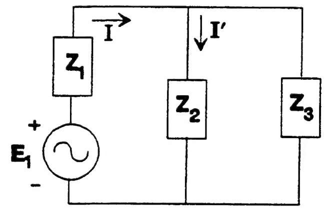
CHAPTER 18 (Odd)

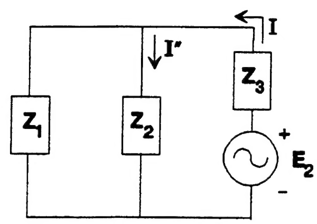
1. a.



$Z_1 = 3\ \Omega\ \angle 0°$, $Z_2 = 8\ \Omega\ \angle 90°$, $Z_3 = 6\ \Omega\ \angle -90°$
$Z_2 \| Z_3 = 8\ \Omega\ \angle 90° \| 6\ \Omega\ \angle -90° = 24\ \Omega\ \angle -90°$

$$I = \frac{E_1}{Z_1 + Z_2 \| Z_3} = \frac{30\ \text{V}\ \angle 30°}{3\ \Omega - j24\ \Omega} = 1.24\ \text{A}\ \angle 112.875°$$

$$I' = \frac{Z_3 I}{Z_2 + Z_3} = \frac{(6\ \Omega\ \angle -90°)(1.24\ \text{A}\ \angle 112.875°)}{2\ \Omega\ \angle 90°} = 3.72\ \text{A}\ \angle -67.125°$$



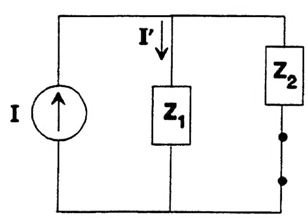
$Z_1 \| Z_2 = 3\ \Omega\ \angle 0° \| 8\ \Omega\ \angle 90° = 2.809\ \Omega\ \angle 20.556°$

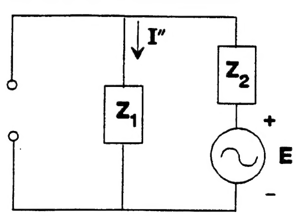
$$I = \frac{E_2}{Z_3 + Z_1 \| Z_2} = \frac{60\ \text{V}\ \angle 10°}{-j6\ \Omega + 2.630\ \Omega + j0.986\ \Omega}$$
$$= 10.597\ \text{A}\ \angle 72.322°$$

$$I'' = \frac{Z_1 I}{Z_1 + Z_2} = \frac{(3\ \Omega\ \angle 0°)(10.597\ \text{A}\ \angle 72.322°)}{3\ \Omega + j8\ \Omega} = 3.721\ \text{A}\ \angle 2.878°$$

$$I_{L_1} = I' + I'' = 3.72\ \text{A}\ \angle -67.125° + 3.721\ \text{A}\ \angle 2.878°$$
$$= 1.446\ \text{A} - j3.427\ \text{A} + 3.716\ \text{A} + j0.187\ \text{A}$$
$$= 5.162\ \text{A} - j3.24\ \text{A}$$
$$= \mathbf{6.095\ A\ \angle -32.115°}$$

b.





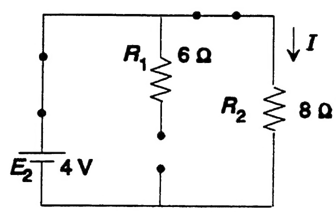
$Z_1 = 8\ \Omega\ \angle 90°$, $Z_2 = 5\ \Omega\ \angle -90°$
$I = 0.3\ \text{A}\ \angle 60°$, $E = 10\ \text{V}\ \angle 0°$

$$I' = \frac{Z_2 I}{Z_2 + Z_1} = \frac{(5\ \Omega\ \angle -90°)(0.3\ \text{A}\ \angle 60°)}{+j8\ \Omega - j5\ \Omega}$$
$$= 0.5\text{A}\ \angle -120°$$

$$I'' = \frac{E}{Z_1 + Z_2} = \frac{10\ \text{V}\ \angle 0°}{3\ \Omega\ \angle 90°} = 3.33\ \text{A}\ \angle -90°$$

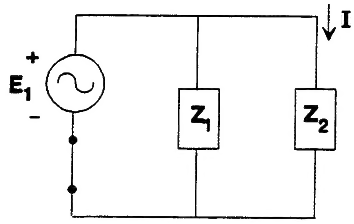
$$I_{Z_1} = I_{L_1} = I' + I''$$
$$= 0.5\ \text{A}\ \angle -120° + 3.33\ \text{A}\ \angle -90°$$
$$= -0.25\ \text{A} - j0.433\ \text{A} - j3.33\ \text{A}$$
$$= -0.25\ \text{A} - j3.763\ \text{A}$$
$$= \mathbf{3.77\ A\ \angle -93.8°}$$

3. DC:



$$I_{DC} = \frac{4\text{ V}}{8\ \Omega} = 0.5\text{ A}$$

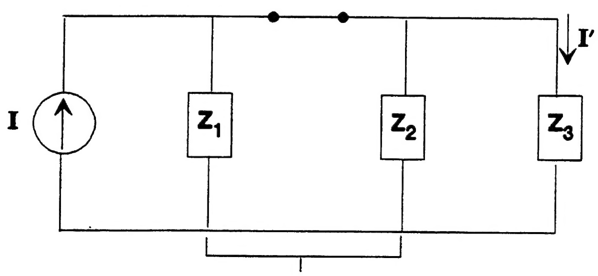
AC:



$$\mathbf{Z}_2 = R_2 + jX_L = 8\ \Omega + j4\ \Omega$$
$$= 8.944\ \Omega\ \angle 26.565°$$
$$\mathbf{I} = \frac{\mathbf{E}_1}{\mathbf{Z}_2} = \frac{10\text{ V}\ \angle 0°}{8.944\ \Omega\ \angle 26.565°}$$
$$= 1.118\text{ A}\ \angle -26.565°$$

$$\mathbf{I = 0.5\text{ A} + 1.118\text{ A}\ \angle -26.565°}$$
$$\boldsymbol{i = 0.5\text{ A} + 1.581\sin(\omega t - 26.565°)}$$

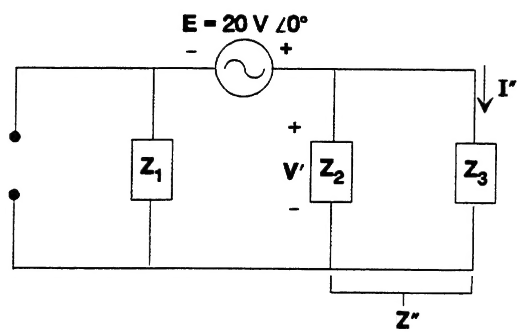
5.



$\mathbf{E} = 20\text{ V}\ \angle 0°$
$\mathbf{Z}_1 = 10\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\text{ k}\Omega - j5\text{ k}\Omega$
$= 7.071\text{ k}\Omega\ \angle -45°$
$\mathbf{Z}_3 = 5\text{ k}\Omega\ \angle 90°$
$\mathbf{I} = 5\text{ mA}\ \angle 0°$

$$\mathbf{Z}' = \mathbf{Z}_1 \| \mathbf{Z}_2 = 10\text{ k}\Omega\ \angle 0° \| 7.071\text{ k}\Omega\ \angle -45° = 4.472\text{ k}\Omega\ \angle -26.57°$$

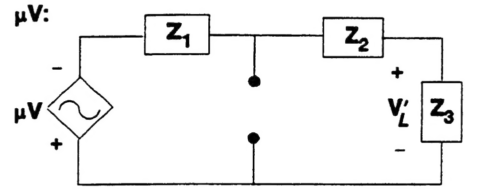
(CDR) $$\mathbf{I}' = \frac{\mathbf{Z}'\mathbf{I}}{\mathbf{Z}' + \mathbf{Z}_3} = \frac{(4.472\text{ k}\Omega\ \angle -26.57°)(5\text{ mA}\ \angle 0°)}{4\text{ k}\Omega - j2\text{ k}\Omega + j5\text{ k}\Omega} = \frac{22.36\text{ mA}\ \angle -26.57°}{5\ \angle 36.87°}$$
$$= 4.472\text{ mA}\ \angle -63.44°$$



$$\mathbf{Z}'' = \mathbf{Z}_2 \| \mathbf{Z}_3$$
$$= 7.071\text{ k}\Omega\ \angle -45° \| 5\text{ k}\Omega\ \angle 90°$$
$$= 7.071\text{ k}\Omega\ \angle 45°$$

(VDR) $$\mathbf{V}' = \frac{\mathbf{Z}''\mathbf{E}}{\mathbf{Z}'' + \mathbf{Z}_1} = \frac{(7.071\text{ k}\Omega\ \angle 45°)(20\text{ V}\ \angle 0°)}{(5\text{ k}\Omega + j5\text{ k}\Omega) + (10\text{ k}\Omega)} = \frac{141.42\text{ V}\ \angle 45°}{15.81\ \angle 18.435°}$$
$$= 8.945\text{ V}\ \angle 26.565°$$
$$\mathbf{I}'' = \frac{\mathbf{V}'}{\mathbf{Z}_3} = \frac{8.945\text{ V}\ \angle 26.565°}{5\text{ k}\Omega\ \angle 90°} = 1.789\text{ mA}\ \angle -63.435° = 0.8\text{ mA} - j1.6\text{ mA}$$
$$\mathbf{I} = \mathbf{I}' + \mathbf{I}'' = (2\text{ mA} - j4\text{ mA}) + (0.8\text{ mA} - j1.6\text{ mA}) = 2.8\text{ mA} - j5.6\text{ mA}$$
$$= \mathbf{6.261\text{ mA}\ \angle -63.43°}$$

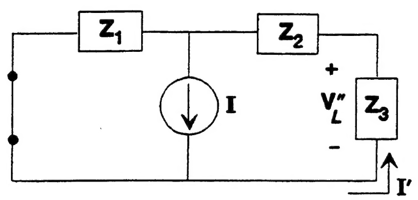
7. μV:



$\mathbf{Z}_1 = 5\text{ k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 1\text{ k}\Omega\ \angle -90°$
$\mathbf{Z}_3 = 4\text{ k}\Omega\ \angle 0°$
$\mathbf{V} = 2\text{ V}\ \angle 0°$, $\mu = 20$

$$\mathbf{V}'_L = \frac{-\mathbf{Z}_3(\mu\mathbf{V})}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3} = \frac{-(4\text{ k}\Omega\ \angle 0°)(20)(2\text{ V}\ \angle 0°)}{5\text{ k}\Omega - j1\text{ k}\Omega + 4\text{ k}\Omega} = -17.67\text{ V}\ \angle 6.34°$$

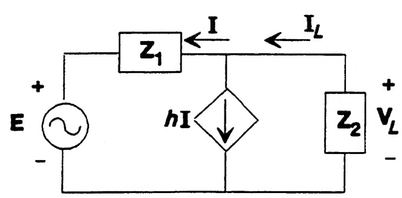
I:



$$\text{CDR: } \mathbf{I}' = \frac{\mathbf{Z}_1\mathbf{I}}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(5\text{ k}\Omega\ \angle 0°)(2\text{ mA}\ \angle 0°)}{9.056\text{ k}\Omega\ \angle -6.34°} = 1.104\text{ mA}\ \angle 6.34°$$

$$\mathbf{V}''_L = -\mathbf{I}'\mathbf{Z}_3 = -(1.104\text{ mA}\ \angle 6.34°)(4\text{ k}\Omega\ \angle 0°) = -4.416\text{ V}\ \angle 6.34°$$
$$\mathbf{V}_L = \mathbf{V}'_L + \mathbf{V}''_L = -17.67\text{ V}\ \angle 6.34° - 4.416\text{ V}\ \angle 6.34° = \mathbf{-22.09\ V\ \angle 6.34°}$$

9.



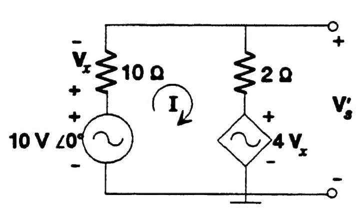
$\mathbf{Z}_1 = 2\text{ k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 2\text{ k}\Omega\ \angle 0°$
$\mathbf{V}_L = -\mathbf{I}_L\mathbf{Z}_2$
$\mathbf{I}_L = h\mathbf{I} + \mathbf{I} = (h + 1)\mathbf{I}$
$\mathbf{V}_L = -(h + 1)\mathbf{I}\mathbf{Z}_2$
and by KVL: $\mathbf{V}_L = \mathbf{I}\mathbf{Z}_1 + \mathbf{E}$
so that $\mathbf{I} = \dfrac{\mathbf{V}_L - \mathbf{E}}{\mathbf{Z}_1}$

$$\mathbf{V}_L = -(h + 1)\mathbf{I}\mathbf{Z}_2 = -(h + 1)\left[\frac{\mathbf{V}_L - \mathbf{E}}{\mathbf{Z}_1}\right]\mathbf{Z}_2$$

Subt. for $\mathbf{Z}_1$, $\mathbf{Z}_2$

$$\mathbf{V}_L = -(h + 1)(\mathbf{V}_L - \mathbf{E})$$
$$\mathbf{V}_L(2 + h) = \mathbf{E}(h + 1)$$
$$\mathbf{V}_L = \frac{(h + 1)}{(h + 2)}\mathbf{E} = \frac{51}{52}(20\text{ V}\ \angle 53°) = \mathbf{19.62\ V\ \angle 53°}$$

11. $\mathbf{E}_1$:

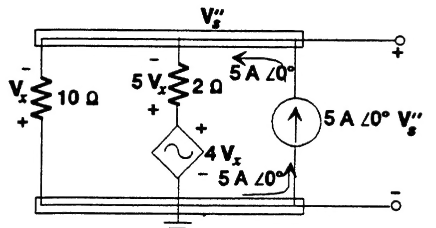


$$10\text{ V}\ \angle 0° - \mathbf{I}\ 10\ \Omega - \mathbf{I}\ 2\ \Omega - 4\ \mathbf{V}_x = 0$$
with $\mathbf{V}_x = \mathbf{I}\ 10\ \Omega$

Solving for **I**:

$$\mathbf{I} = \frac{10\text{ V}\ \angle 0°}{52\ \Omega} = 192.31\text{ mA}\ \angle 0°$$
$$\mathbf{V}'_s = 10\text{ V}\ \angle 0° - \mathbf{I}(10\ \Omega) = 10\text{ V} - (192.31\text{ mA}\ \angle 0°)(10\ \Omega\ \angle 0°) = 8.08\text{ V}\ \angle 0°$$

I:



$$\Sigma I_i = \Sigma I_o$$

$$5\text{ A }\angle 0° + \frac{\mathbf{V}_x}{10\ \Omega} + \frac{5\ \mathbf{V}_x}{2\ \Omega} = 0$$

$$5\text{ A} + 0.1\ \mathbf{V}_x + 2.5\ \mathbf{V}_x = 0$$

$$2.6\ \mathbf{V}_x = -5\text{ A}$$

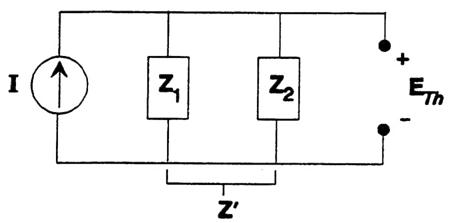
$$\mathbf{V}_x = -\frac{5}{2.6}\text{V} = -1.923\text{ V}$$

$$\mathbf{V}_s'' = -\mathbf{V}_x = -(-1.923\text{ V}) = 1.923\text{ V }\angle 0°$$

$$\mathbf{V}_s = \mathbf{V}_s' + \mathbf{V}_s'' = 8.08\text{ V }\angle 0° + 1.923\text{ V }\angle 0° = \mathbf{10\text{ V }\angle 0°}$$

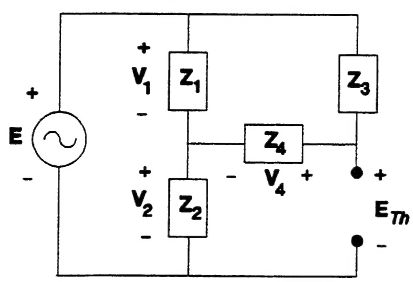
13. a. From #27. $\mathbf{Z}_{Th} = \mathbf{Z}_1 \| \mathbf{Z}_2$

$\mathbf{Z}_{Th} = \mathbf{Z}_N = \mathbf{21.312\ \Omega\ \angle 32.196°}$



$$\mathbf{E}_{Th} = \mathbf{IZ}' = \mathbf{IZ}_{Th}$$
$$= (0.1\text{ A }\angle 0°)(21.312\ \Omega\ \angle 32.196°)$$
$$= \mathbf{2.131\text{ V}\angle 32.196°}$$

b. From #27. $\mathbf{Z}_{Th} = \mathbf{Z}_N = \mathbf{6.813\ \Omega\ \angle -54.228°} = 3.983\ \Omega - j5.528\ \Omega$



$\mathbf{Z}_1 = 2\ \Omega\ \angle 0°$, $\mathbf{Z}_3 = 8\ \Omega \angle -90°$

$\mathbf{Z}_2 = 4\ \Omega\ \angle 90°$, $\mathbf{Z}_4 = 10\ \Omega\ \angle 0°$

$\mathbf{E} = 50\text{ V }\angle 0°$

$\mathbf{E}_{Th} = \mathbf{V}_2 + \mathbf{V}_4$

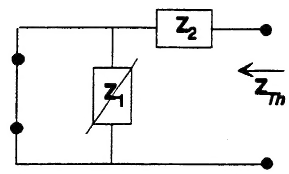
$$\mathbf{V}_2 = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1 \| (\mathbf{Z}_3 + \mathbf{Z}_4)}$$
$$= \frac{(4\ \Omega\ \angle 90°)(50\text{ V }\angle 0°)}{+j4\ \Omega + 2\ \Omega\ \angle 0° \| (10\ \Omega - j8\ \Omega)}$$
$$= 47.248\text{ V }\angle 24.7°$$

$$\mathbf{V}_1 = \mathbf{E} - \mathbf{V}_2 = 50\text{ V }\angle 0° - 47.248\text{ V }\angle 24.7° = 20.972\text{ V }\angle -70.285°$$

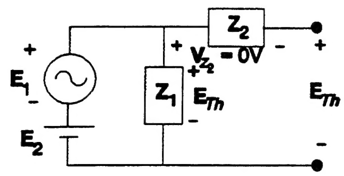
$$\mathbf{V}_4 = \frac{\mathbf{Z}_4\mathbf{V}_1}{\mathbf{Z}_4 + \mathbf{Z}_3} = \frac{(10\ \Omega\ \angle 0°)(20.972\text{ V }\angle -70.285°)}{10\ \Omega - j8\ \Omega} = 16.377\text{ V }\angle -31.625°$$

$$\mathbf{E}_{Th} = \mathbf{V}_2 + \mathbf{V}_4 = 47.248\text{ V }\angle 24.7° + 16.377\text{ V }\angle -31.625°$$
$$= (42.925\text{ V} + j19.743\text{ V}) + (13.945\text{ V} - j8.587\text{ V})$$
$$= 56.870\text{ V} + j11.156\text{ V} = \mathbf{57.954\text{ V }\angle 11.099°}$$

15. a.



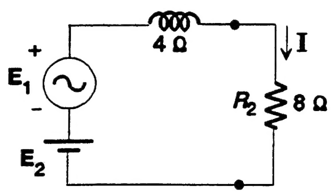
$Z_1 = 6\ \Omega - j2\ \Omega = 6.325\ \Omega\ \angle -18.435°$
$Z_2 = 4\ \Omega\ \angle 90°$
$Z_{Th} = Z_2 = \mathbf{4\ \Omega\ \angle 90°}$



By inspection:

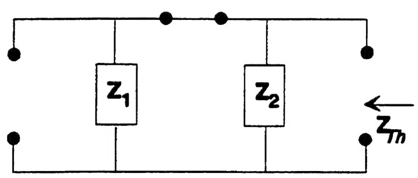
$$\mathbf{E}_{Th} = E_2 + \mathbf{E}_1 = \underset{\text{DC}}{4\ \text{V}} + \underset{\text{AC}}{10\ \text{V}}\ \angle 0°$$

b.



$$\mathbf{I} = \frac{E_2}{R_2} + \frac{\mathbf{E}_1}{R_2 + jX_L} = \frac{4\ \text{V}}{8\ \Omega} + \frac{10\ \text{V}\ \angle 0°}{8\ \Omega + j4\ \Omega}$$
$$= 0.5\ \text{A} + \frac{10\ \text{V}\ \angle 0°}{8.944\ \Omega\ \angle 26.565°}$$
$$= \underset{\text{(dc)}}{0.5\ \text{A}} + \underset{\text{(ac)}}{1.118\ \text{A}\ \angle -26.565°}$$

17. a. Z_{Th}:

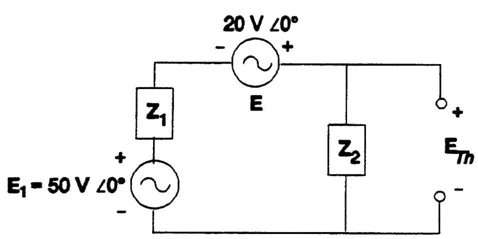


$Z_1 = 10\ \text{k}\Omega\ \angle 0°$
$Z_2 = 5\ \text{k}\Omega - j5\ \text{k}\Omega = 7.071\ \text{k}\Omega\ \angle -45°$

$$Z_{Th} = Z_1 \| Z_2 = (10\ \text{k}\Omega\ \angle 0°) \| (7.071\ \text{k}\Omega\ \angle -45°) = \mathbf{4.472\ k\Omega\ \angle -26.565°}$$

Source conversion:

$$\mathbf{E}_1 = (I \angle \theta)(R_1 \angle 0°) = (5\ \text{mA}\ \angle 0°)(10\ \text{k}\Omega\ \angle 0°) = 50\ \text{V}\ \angle 0°$$

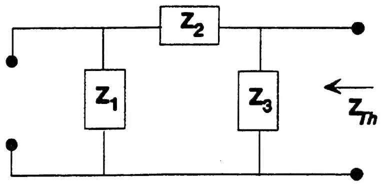


$$\mathbf{E}_{Th} = \frac{Z_2(\mathbf{E} + \mathbf{E}_1)}{Z_2 + Z_1} = \frac{(7.071\ \text{k}\Omega\ \angle -45°)(20\ \text{V}\ \angle 0° + 50\ \text{V}\ \angle 0°)}{(5\ \text{k}\Omega - j5\ \text{k}\Omega) + (10\ \text{k}\Omega)}$$
$$= \frac{(7.071\ \text{k}\Omega\ \angle -45°)(70\ \text{V}\ \angle 0°)}{(15\ \text{k}\Omega - j5\ \text{k}\Omega)} = \frac{494.97\ \text{V}\ \angle -45°}{15.811\ \angle -18.435°}$$
$$= \mathbf{31.31\ V\ \angle -26.565°}$$

b.

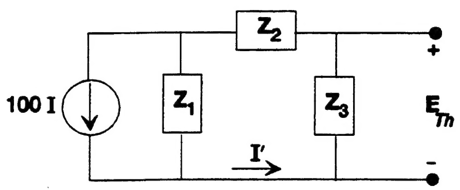
$$\mathbf{I} = \frac{\mathbf{E}_{Th}}{\mathbf{Z}_{Th} + \mathbf{Z}_L} = \frac{31.31\ \text{V}\ \angle -26.565°}{4.472\ \text{k}\Omega\ \angle -26.565° + 5\ \text{k}\Omega\ \angle 90°}$$
$$= \frac{31.31\ \text{V}\ \angle -26.565°}{4\ \text{k}\Omega - j2\ \text{k}\Omega + j5\ \text{k}\Omega} = \frac{31.31\ \text{V}\ \angle -26.565°}{4\ \text{k}\Omega + j3\ \text{k}\Omega}$$
$$= \frac{31.31\ \text{V}\ \angle -26.565°}{5\ \text{k}\Omega\ \angle 36.87°} = \mathbf{6.26\ mA\ \angle 63.435°}$$

19. $\mathbf{Z}_{Th}$:



$\mathbf{Z}_1 = 40\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 0.2\ \text{k}\Omega\ \angle -90°$
$\mathbf{Z}_3 = 5\ \text{k}\Omega\ \angle 0°$

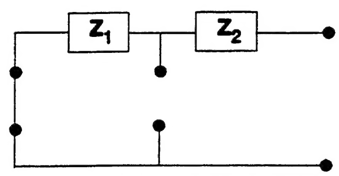
$$\mathbf{Z}_{Th} = \mathbf{Z}_3 \| (\mathbf{Z}_1 + \mathbf{Z}_2) = 5\ \text{k}\Omega\ \angle 0° \| (40\ \text{k}\Omega - j0.2\ \text{k}\Omega) = \mathbf{4.44\ k\Omega\ \angle -0.031°}$$



$$\mathbf{I}' = \frac{\mathbf{Z}_1(100\ \mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(40\ \text{k}\Omega\ \angle 0°)(100\ \mathbf{I})}{45\ \text{k}\Omega\ \angle -0.255°} = 88.89\ \mathbf{I}\ \angle 0.255°$$

$$\mathbf{E}_{Th} = -\mathbf{I}'\mathbf{Z}_3 = -(88.89\ \mathbf{I}\ \angle 0.255°)(5\ \text{k}\Omega\ \angle 0°) = \mathbf{-444.45 \times 10^3\ I\ \angle 0.255°}$$

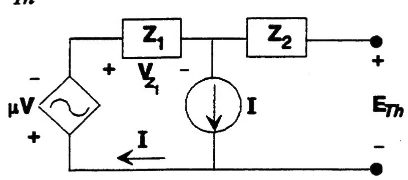
21. $\mathbf{Z}_{Th}$:



$\mathbf{Z}_1 = 5\ \text{k}\Omega\ \angle 0°$ $\qquad$ $\mathbf{Z}_2 = -j1\ \text{k}\Omega$

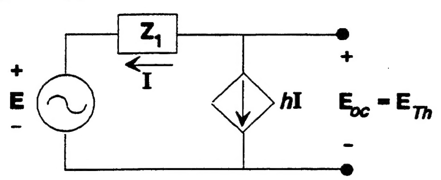
$$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 + \mathbf{Z}_2 = 5\ \text{k}\Omega - j1\ \text{k}\Omega = 5.099\ \text{k}\Omega\ \angle -11.31°$$

$\mathbf{E}_{Th}$:



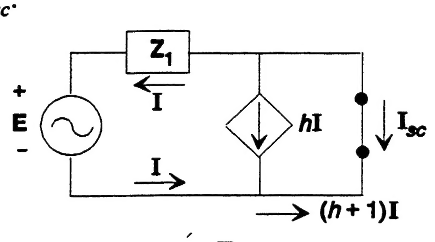
$$\mathbf{E}_{Th} = -[\mu\mathbf{V} + \mathbf{V}_{Z_1}] = -\mu\mathbf{V} - \mathbf{I}\mathbf{Z}_1 = -(20)(2\ \text{V}\ \angle 0°) - (2\ \text{mA}\ \angle 0°)(5\ \text{k}\Omega\ \angle 0°) = \mathbf{-50\ V\ \angle 0°}$$

23. $\mathbf{E}_{Th}$: ($\mathbf{E}_{oc}$)



$h\mathbf{I} = -\mathbf{I}$ $\qquad$ $\mathbf{Z}_1 = 2\ \text{k}\Omega\ \angle 0°$
$\therefore$ $\mathbf{I} = 0$
and $h\mathbf{I} = 0$
with $\mathbf{E}_{oc} = \mathbf{E}_{Th} = \mathbf{E} = \mathbf{20\ V\ \angle 53°}$

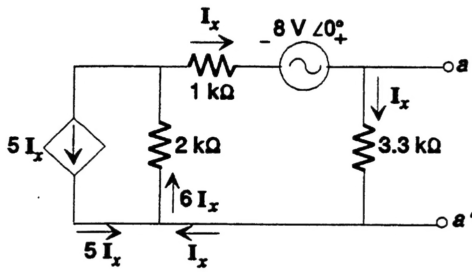
$\mathbf{I}_{sc}$:



$$\mathbf{I}_{sc} = -(h + 1)\mathbf{I} = -(h + 1)(10\ \text{mA}\ \angle 53°) = -510\ \text{mA}\ \angle 53°$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{20\ \text{V}\ \angle 53°}{-510\ \text{mA}\ \angle 53°} = \mathbf{-39.215\ \Omega\ \angle 0°}$$

25. $\mathbf{E}_{oc}$:
($\mathbf{E}_{Th}$)

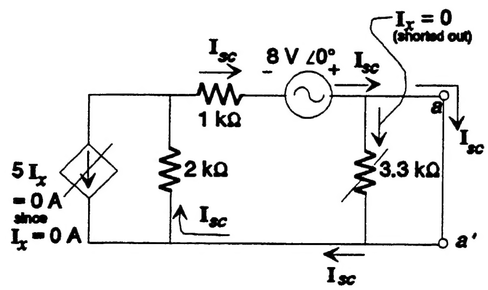


$$\text{KVL: } -6\,\mathbf{I}_x(2\text{ k}\Omega) - \mathbf{I}_x(1\text{ k}\Omega) + 8\text{ V}\angle 0^\circ - \mathbf{I}_x(3.3\text{ k}\Omega) = 0$$

$$\mathbf{I}_x = \frac{8\text{ V }\angle 0^\circ}{16.3\text{ k}\Omega} = 0.491\text{ mA }\angle 0^\circ$$

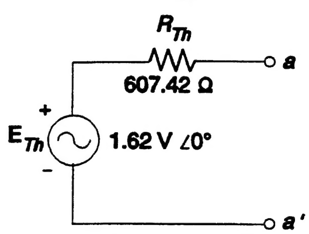
$$\mathbf{E}_{oc} = \mathbf{E}_{Th} = \mathbf{I}_x(3.3\text{ k}\Omega) = \mathbf{1.62\text{ V }\angle 0^\circ}$$

$\mathbf{I}_{sc}$:

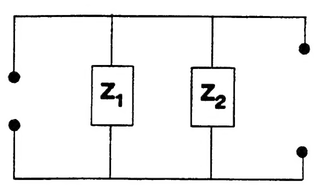


$$\mathbf{I}_{sc} = \frac{8\text{ V}}{3\text{ k}\Omega} = 2.667\text{ mA }\angle 0^\circ$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{1.62\text{ V }\angle 0^\circ}{2.667\text{ mA }\angle 0^\circ} = \mathbf{607.42\ \Omega}$$

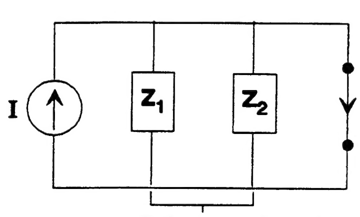


27. a.



$\mathbf{Z}_1 = 20\ \Omega + j20\ \Omega = 28.284\ \Omega\ \angle 45^\circ$
$\mathbf{Z}_2 = 68\ \Omega\ \angle 0^\circ$

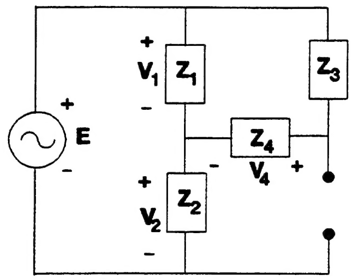
$\leftarrow \mathbf{Z}_N = \mathbf{Z}_1 \parallel \mathbf{Z}_2$
$= (28.284\ \Omega\ \angle 45^\circ) \parallel (68\ \Omega\ \angle 0^\circ)$
$= 21.312\ \Omega\ \angle 32.196^\circ$



Z′ bypassed by short-circuit

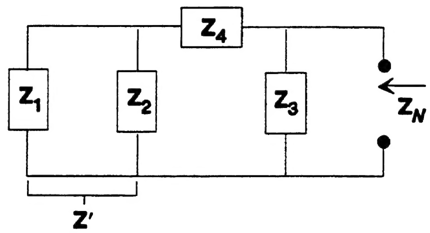
$\mathbf{I}_{sc} = \mathbf{I} = \mathbf{I}_N = 0.1\text{ A }\angle 0^\circ$

b.

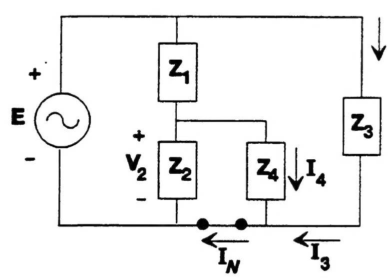


$Z_1 = 2\ \Omega\ \angle 0°$, $Z_2 = 4\ \Omega\ \angle 90°$
$Z_3 = 8\ \Omega\ \angle -90°$, $Z_4 = 10\ \Omega\ \angle 0°$
$E = 50\ V\ \angle 0°$

Z_N:



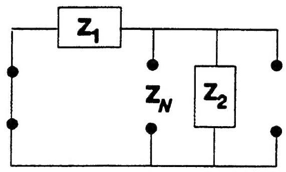
$$Z' = Z_1 \| Z_2 = 2\ \Omega\ \angle 0° \| 4\ \Omega\ \angle 90°$$
$$= 1.789\ \Omega\ \angle 26.565° = 1.6\ \Omega + j0.8\ \Omega$$
$$Z' + Z_4 = 1.6\ \Omega + j0.8\ \Omega + 10\ \Omega = 11.6\ \Omega + j0.8\ \Omega = 11.628\ \Omega\ \angle 3.945°$$
$$Z_N = Z_3 \| (Z' + Z_4) = (8\ \Omega\ \angle -90°) \| (11.628\ \Omega\ \angle 3.945°) = \mathbf{6.813\ \Omega\ \angle -54.228°}$$
$$= \mathbf{3.983\ \Omega - j5.528\ \Omega}$$



$$I_3 = \frac{E}{Z_3} = \frac{50\ V\ \angle 0°}{8\ \Omega\ \angle -90°} = 6.250\ A\ \angle 90°$$
$$Z' = Z_2 \| Z_4 = 4\ \Omega\ \angle 90° \| 10\ \Omega\ \angle 0°$$
$$= 3.714\ \Omega\ \angle 68.2°$$
$$V_2 = \frac{Z'E}{Z' + Z_1} = \frac{(3.714\ \Omega\ \angle 68.2°)(50\ V\ \angle 0°)}{1.378\ \Omega + j3.448\ \Omega + 2\ \Omega}$$
$$= \frac{185.7\ V\ \angle 68.2°}{4.827\ \angle 45.588°} = 38.471\ V\ \angle 22.612°$$

$$I_4 = \frac{V_2}{Z_4} = \frac{38.471\ V\ \angle 22.612°}{10\ \Omega\ \angle 0°} = 3.847\ A\ \angle 22.612°$$
$$I_N = I_3 + I_4 = 6.250\ A\ \angle 90° + 3.847\ A\ \angle 22.612°$$
$$= +j6.25\ A + 3.551\ A + j1.479\ A = 3.551\ A + j7.729\ A$$
$$= \mathbf{8.506\ A\ \angle 65.324°}$$

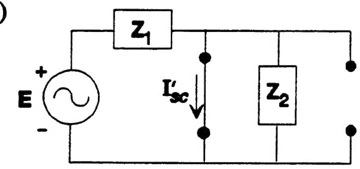
29. a. $\mathbf{Z}_N$:



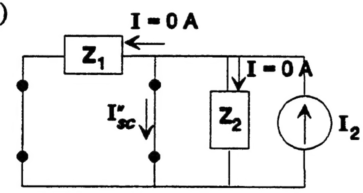
$\mathbf{E} = 20\text{ V}\ \angle 0°$, $\mathbf{I}_2 = 0.4\text{ A}\ \angle 20°$
$\mathbf{Z}_1 = 6\ \Omega + j8\ \Omega = 10\ \Omega\ \angle 53.13°$
$\mathbf{Z}_2 = 9\ \Omega - j12\ \Omega = 15\ \Omega\ \angle -53.13°$
$\mathbf{Z}_N = \mathbf{Z}_1 \| \mathbf{Z}_2 = (10\ \Omega\ \angle 53.13°) \| (15\ \Omega\ \angle -53.13°)$
$= \mathbf{9.66\ \Omega\ \angle 14.93°}$

$\mathbf{I}_N$:

(E)



($\mathbf{I}_2$)

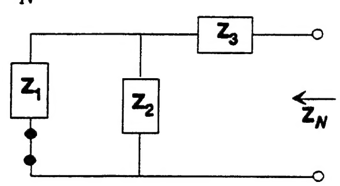


$\mathbf{I}'_{sc} = \mathbf{E}/\mathbf{Z}_1 = 20\text{ V}\ \angle 0°/10\ \Omega\ \angle 53.13°$
$= 2\text{ A}\ \angle -53.13°$

$\mathbf{I}''_{sc} = \mathbf{I}_2 = 0.4\text{ A}\ \angle 20°$

$\mathbf{I}_N = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = 2\text{A}\ \angle -53.13° + 0.4\text{ A}\ \angle 20°$
$= \mathbf{2.15\text{ A}\ \angle -42.87°}$

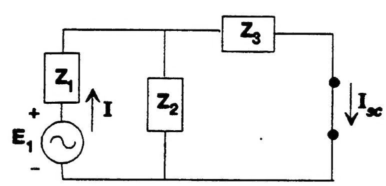
b. $\mathbf{Z}_N$:



$\mathbf{E}_1 = 120\text{ V}\ \angle 30°$, $\mathbf{Z}_1 = 3\ \Omega\ \angle 0°$
$\mathbf{Z}_2 = 8\ \Omega - j8\ \Omega$, $\mathbf{Z}_3 = 4\ \Omega\ \angle 90°$

$\mathbf{Z}_N = \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2$
$= 4\ \Omega\ \angle 90° + (3\ \Omega\ \angle 0°) \| (8\ \Omega - j8\ \Omega)$
$= \mathbf{4.37\ \Omega\ \angle 55.67° = 2.465\ \Omega + j3.61\ \Omega}$

$\mathbf{I}_N$:

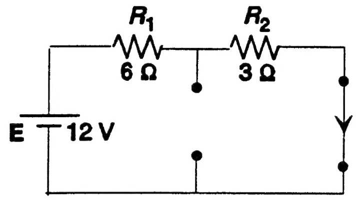


$$\mathbf{I} = \frac{\mathbf{E}_1}{\mathbf{Z}_T} = \frac{120\text{ V}\ \angle 30°}{\mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3}$$
$$= \frac{120\text{ V}\ \angle 30°}{3\ \Omega + (8\ \Omega - j8\ \Omega) \| 4\ \Omega\ \angle 90°}$$
$$= \frac{120\text{ V}\ \angle 30°}{6.65\ \Omega\ \angle 46.22°}$$
$$= 18.05\text{ A}\ \angle -16.22°$$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{Z}_2(\mathbf{I})}{\mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(8\ \Omega - j8\ \Omega)(18.05\text{ A}\ \angle -16.22°)}{8\ \Omega - j8\ \Omega + j4\ \Omega} = \mathbf{22.83\text{ A}\ \angle -34.65°}$$

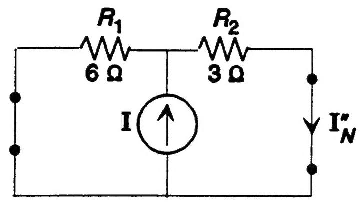
31. a. From #15 $\mathbf{Z}_N = \mathbf{Z}_{Th} = 9\ \Omega\ \angle 0°$

DC:



$$\mathbf{I}'_N = \frac{E}{R_T} = \frac{12\text{ V}}{9\ \Omega} = 1.333\text{ A}$$

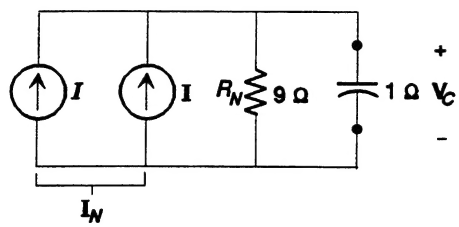
AC:



$$\mathbf{I}''_N = \frac{R_1\mathbf{I}}{R_1 + R_2} = \frac{(6\ \Omega\ \angle 0°)(4\text{ A}\ \angle 0°)}{9\ \Omega\ \angle 0°}$$
$$= \frac{24\text{ V}\ \angle 0°}{9\ \Omega\ \angle 0°} = 2.667\text{ A}\ \angle 0°$$

$\mathbf{I}_N = 1.333\text{ A} + 2.667\text{ A}\ \angle 0°$

b.

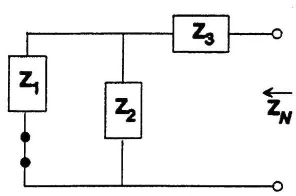


DC: $V_C = IR$
$= (1.333\text{ A})(9\ \Omega)$
$= 12\text{ V}$

AC: $\mathbf{Z}' = 9\ \Omega\ \angle 0° \parallel 1\ \Omega\ \angle -90°$
$= 0.994\ \Omega\ \angle -83.66°$

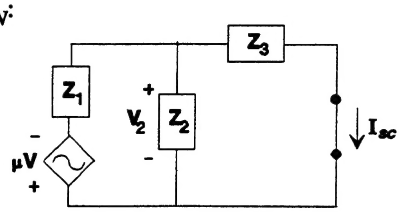
$V_C = \mathbf{I}\mathbf{Z}' = (2.667\text{ A}\ \angle 0°)(0.994\ \Omega\ \angle -83.66°)$
$= 2.65\text{ V}\ \angle -83.66°$
$V_C = 12\text{ V} + 2.65\text{ V}\ \angle -83.66°$

33. $\mathbf{Z}_N$:



$\mathbf{Z}_1 = 10\text{ k}\Omega\ \angle 0°,\ \mathbf{Z}_2 = 10\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_3 = -j1\text{ k}\Omega$
$\mathbf{Z}_N = \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2 = 5\text{ k}\Omega - j1\text{ k}\Omega$
$= 5.1\text{ k}\Omega\ \angle -11.31°$

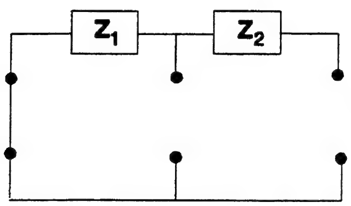
$\mathbf{I}_N$:



$$\mathbf{V}_2 = \frac{-(\mathbf{Z}_2 \parallel \mathbf{Z}_3)20\text{ V}}{(\mathbf{Z}_2 \parallel \mathbf{Z}_3) + \mathbf{Z}_1}$$
$$= \frac{-(0.995\text{ k}\Omega\ \angle -84.29°)(20\text{ V})}{0.1\text{ k}\Omega - j0.99\text{ k}\Omega + 10\text{ k}\Omega}$$
$$\mathbf{V}_2 = -1.961\text{ V}\ \angle -78.69°$$

$$\mathbf{I}_N = \mathbf{I}_{sc} = \frac{\mathbf{V}_2}{\mathbf{Z}_3} = \frac{-1.961\text{ V}\ \angle -78.69°}{1\text{ k}\Omega\ \angle -90°} = -1.961 \times 10^{-3}\text{ V}\ \angle 11.31°$$

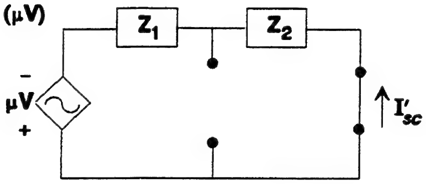
35. $\mathbf{Z}_N$:



$\mathbf{Z}_1 = 5\text{ k}\Omega \angle 0°$, $\mathbf{Z}_2 = 1\text{ k}\Omega \angle -90°$

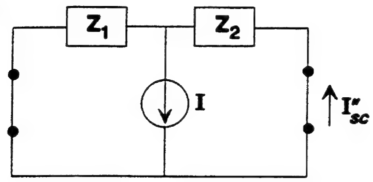
$$\leftarrow \mathbf{Z}_N = \mathbf{Z}_1 + \mathbf{Z}_2 = 5\text{ k}\Omega - j1\text{ k}\Omega$$
$$= 5.1\text{ k}\Omega \angle -11.31°$$

$\mathbf{I}_N$: (μV)



$$\mathbf{I}'_{sc} = \frac{\mu\mathbf{V}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20)(2\text{ V} \angle 0°)}{5.1\text{ k}\Omega \angle -11.31°}$$
$$= 7.843\text{ mA} \angle 11.31°$$

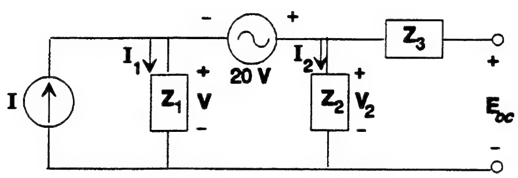
(I)



$$\mathbf{I}''_{sc} = \frac{\mathbf{Z}_1(\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2}$$
$$= \frac{(5\text{ k}\Omega \angle 0°)(2\text{ mA} \angle 0°)}{5.1\text{ k}\Omega \angle -11.31°}$$
$$= 1.96\text{ mA} \angle 11.31°$$

$$\mathbf{I}_N = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = 7.843\text{ mA} \angle 11.31° + 1.96\text{ mA} \angle 11.31°$$
$$= \mathbf{9.81\text{ mA} \angle 11.31°}$$

37.



$\mathbf{Z}_1 = 1\text{ k}\Omega \angle 0°$
$\mathbf{Z}_2 = 3\text{ k}\Omega \angle 0°$
$\mathbf{Z}_3 = 4\text{ k}\Omega \angle 0°$

$$\mathbf{V}_2 = 21\text{ V} = \mathbf{E}_{oc} \Rightarrow \mathbf{V} = \frac{\mathbf{E}_{oc}}{21}$$

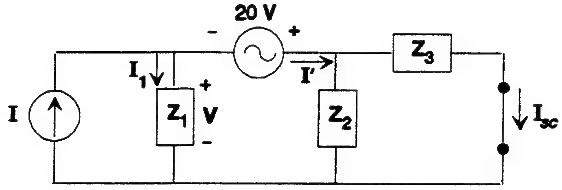
$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2,\ \mathbf{I}_1 = \frac{\mathbf{V}}{\mathbf{Z}_1} = \frac{\mathbf{E}_{oc}}{21\,\mathbf{Z}_1}$$

$$\mathbf{I}_2 = \frac{\mathbf{E}_{oc}}{\mathbf{Z}_2},\quad \mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 = \frac{\mathbf{E}_{oc}}{21\,\mathbf{Z}_1} + \frac{\mathbf{E}_{oc}}{\mathbf{Z}_2} = \mathbf{E}_{oc}\left[\frac{1}{21\,\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_2}\right]$$

$$\mathbf{I} = \mathbf{E}_{oc}\left[\frac{\mathbf{Z}_2 + 21\,\mathbf{Z}_1}{21\,\mathbf{Z}_1\mathbf{Z}_2}\right]$$

and $$\mathbf{E}_{oc} = \frac{21\,\mathbf{Z}_1\mathbf{Z}_2\mathbf{I}}{\mathbf{Z}_2 + 21\,\mathbf{Z}_1} = \frac{(21)(1\text{ k}\Omega \angle 0°)(3\text{ k}\Omega \angle 0°)(2\text{ mA} \angle 0°)}{3\text{ k}\Omega + 21(1\text{ k}\Omega \angle 0°)}$$

$$\mathbf{E}_{Th} = \mathbf{E}_{oc} = \mathbf{5.25\text{ V} \angle 0°}$$



$$\mathbf{I}_{sc} = \frac{\mathbf{V}_3}{\mathbf{Z}_3} = \frac{21\text{ V}}{\mathbf{Z}_3} \Rightarrow \mathbf{V} = \frac{\mathbf{Z}_3}{21}\mathbf{I}_{sc}$$
$$\mathbf{V} = \mathbf{I}_1\mathbf{Z}_1$$
$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}'$$

$$\mathbf{I}_{sc} = \frac{\mathbf{Z}_2\mathbf{I}'}{\mathbf{Z}_2 + \mathbf{Z}_3} \Rightarrow \mathbf{I}' = \left[\frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right]\mathbf{I}_{sc}$$

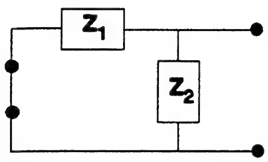
$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}' = \frac{\mathbf{V}}{\mathbf{Z}_1} + \left[\frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right]\mathbf{I}_{sc} = \left[\frac{\mathbf{Z}_3}{21\ \mathbf{Z}_1} + \frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right]\mathbf{I}_{sc}$$

$$\mathbf{I}_{sc} = \frac{\mathbf{I}}{\dfrac{\mathbf{Z}_3}{21\ \mathbf{Z}_1} + \dfrac{\mathbf{Z}_3 + \mathbf{Z}_2}{\mathbf{Z}_2}} = \frac{2\text{ mA }\angle 0^\circ}{\dfrac{4\text{ k}\Omega}{21\text{ k}\Omega} + \dfrac{7\text{ k}\Omega}{3\text{ k}\Omega}} = 0.792\text{ mA }\angle 0^\circ$$

$\therefore$ $\mathbf{I}_N = \mathbf{0.792\ mA\ \angle 0^\circ}$

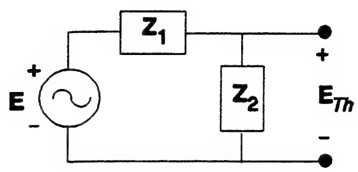
$$\mathbf{Z}_N = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{5.25\text{ V }\angle 0^\circ}{0.792\text{ mA }\angle 0^\circ} = \mathbf{6.63\ k\Omega\ \angle 0^\circ}$$

39. a.



$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega,\ \mathbf{Z}_2 = -j6\ \Omega$

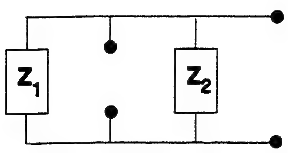
$$\begin{aligned}\leftarrow \mathbf{Z}_{Th} &= \mathbf{Z}_1 \parallel \mathbf{Z}_2\\ &= 5\ \Omega\ \angle 53.13^\circ \parallel 6\ \Omega\ \angle -9\\ &= 8.32\ \Omega\ \angle -3.18^\circ\\ \mathbf{Z}_L &= 8.32\ \Omega\ \angle 3.18^\circ = \mathbf{8.31\ \Omega - \mathit{j}0.462\ \Omega}\end{aligned}$$



$$\begin{aligned}\mathbf{E}_{Th} &= \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1}\\ &= \frac{(6\ \Omega\ \angle -90^\circ)(120\text{ V }\angle 0^\circ)}{3.61\ \Omega\ \angle -33.69^\circ}\\ &= \mathbf{199.45\ V\ \angle -56.31^\circ}\end{aligned}$$

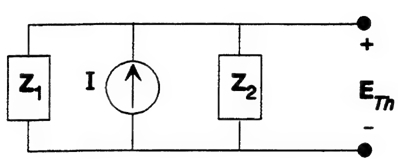
$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(199.45\text{ V})^2}{4(8.31\ \Omega)} = \mathbf{1198.2\ W}$$

b.



$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13^\circ$
$\mathbf{Z}_2 = 2\ \Omega\ \angle 0^\circ$

$$\begin{aligned}\leftarrow \mathbf{Z}_N = \mathbf{Z}_{Th} &= \mathbf{Z}_1 \parallel \mathbf{Z}_2\\ &= 5\ \Omega\ \angle 53.13^\circ \parallel 2\ \Omega\ \angle 0^\circ\\ &= \frac{10\ \Omega\ \angle 53.13^\circ}{2 + 3 + j4}\\ &= \frac{10\ \Omega\ \angle 53.13^\circ}{5 + j4}\\ &= \frac{10\ \Omega\ \angle 53.13^\circ}{6.403\ \angle 38.66^\circ}\\ &= \mathbf{1.562\ \Omega\ \angle 14.47^\circ}\\ \mathbf{Z}_{Th} &= 1.562\ \Omega\ \angle 14.47^\circ\\ &= 1.512\ \Omega + j0.39\ \Omega\\ \mathbf{Z}_L &= \mathbf{1.512\ \Omega - \mathit{j}0.39\ \Omega}\end{aligned}$$



$$\begin{aligned}\mathbf{E}_{Th} &= \mathbf{I}(\mathbf{Z}_1 \parallel \mathbf{Z}_2)\\ &= (2\text{ A }\angle 30^\circ)(1.562\ \Omega\ \angle 14.47^\circ)\\ &= \mathbf{3.124\ V\ \angle 44.47^\circ}\end{aligned}$$

$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(3.124\text{ V})^2}{4(1.512\ \Omega)} = \mathbf{1.614\ W}$$

41. $\mathbf{I} = \dfrac{E\angle 0°}{R_1\angle 0°} = \dfrac{1\text{ V}\ \angle 0°}{1\text{ k}\Omega\ \angle 0°} = 1\text{ mA}\ \angle 0°$

$\mathbf{Z}_{Th} = 40\text{ k}\Omega\ \angle 0°$

$\mathbf{E}_{Th} = (50\ \mathbf{I})(40\text{ k}\Omega\ \angle 0°) = (50)(1\text{ mA}\ \angle 0°)(40\text{ k}\Omega\ \angle 0°) = 2000\text{ V}\ \angle 0°$

$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(2\text{ kV})^2}{4(40\text{ k}\Omega)} = \mathbf{25\text{ W}}$$

43. From #16, $\mathbf{Z}_{Th} = 9\ \Omega$, $\mathbf{E}_{Th} = 12\text{ V} + 24\text{ V}\ \angle 0°$

a. $\therefore Z_L = 9\ \Omega$

b. $$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(12\text{ V})^2}{4(9\ \Omega)} + \frac{(24\text{ V})^2}{4(9\ \Omega)} = 4\text{ W} + 16\text{ W} = \mathbf{20\text{ W}}$$

or $E_{Th} = \sqrt{V_0^2 + {V_{1_{\text{eff}}}}^2} = 26.833\text{ V}$

and $P_{\max} = \dfrac{E_{Th}^2}{4R_{Th}} = \dfrac{(26.833\text{ V})^2}{4(9\ \Omega)} = \mathbf{20\text{ W}}$

45. a. $\mathbf{Z}_{Th} = 2\text{ k}\Omega\ \angle 0° \,\|\, 2\text{ k}\Omega\ \angle -90° = 1\text{ k}\Omega - j1\text{ k}\Omega$

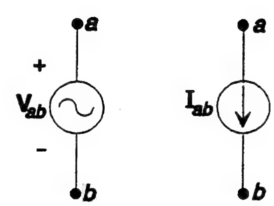
$$\begin{aligned} R_L &= \sqrt{R_{Th}^2 + (X_{Th} + X_{\text{Load}})^2} \\ &= \sqrt{(1\text{ k}\Omega)^2 + (-1\text{ k}\Omega + 2\text{ k}\Omega)^2} \\ &= \sqrt{(1\text{ k}\Omega)^2 + (1\text{ k}\Omega)^2} \\ &= \mathbf{1.414\text{ k}\Omega} \end{aligned}$$

b. $R_{\text{av}} = (R_{Th} + R_{\text{Load}})/2 = (1\text{ k}\Omega + 1.414\text{ k}\Omega)/2 = 1.207\text{ k}\Omega$

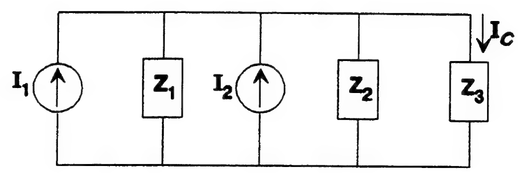
$$P_{\max} = \frac{E_{Th}^2}{4R_{\text{av}}} = \frac{(50\text{ V})^2}{4(1.207\text{ k}\Omega)} = \mathbf{0.518\text{ W}}$$

47. $\mathbf{I}_{ab} = \dfrac{(4\text{ k}\Omega\ \angle 0°)(4\text{ mA}\ \angle 0°)}{4\text{ k}\Omega + 8\text{ k}\Omega} = \mathbf{1.333\text{ mA}\ \angle 0°}$

$\mathbf{V}_{ab} = (\mathbf{I}_{ab})(8\text{ k}\Omega\ \angle 0°) = \mathbf{10.67\text{ V}\ \angle 0°}$



49.



$$\mathbf{I}_1 = \frac{100\text{ V}\ \angle 0^\circ}{2\text{ k}\Omega\ \angle 0^\circ} = 50\text{ mA}\ \angle 0^\circ$$

$$\mathbf{I}_2 = \frac{50\text{ V}\ \angle 0^\circ}{4\text{ k}\Omega\ \angle 90^\circ}$$
$$= 12.5\text{ mA}\ \angle -90^\circ$$

$\mathbf{Z}_1 = 2\text{ k}\Omega\ \angle 0^\circ$
$\mathbf{Z}_2 = 4\text{ k}\Omega\ \angle 90^\circ$
$\mathbf{Z}_3 = 4\text{ k}\Omega\ \angle -90^\circ$

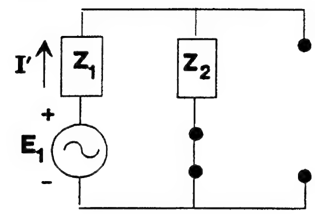
$$\mathbf{I}_T = \mathbf{I}_1 - \mathbf{I}_2 = (50\text{ mA}\ \angle 0^\circ - 12.5\text{ mA}\ \angle -90^\circ) = 50\text{ mA} + j12.5\text{ mA}$$
$$= 51.54\text{ mA}\ \angle 14.04^\circ$$

$$\mathbf{Z}' = \mathbf{Z}_1 \| \mathbf{Z}_2 = (2\text{ k}\Omega\ \angle 0^\circ) \| (4\text{ k}\Omega\ \angle 90^\circ) = 1.79\text{ k}\Omega\ \angle 26.57^\circ$$

$$\mathbf{I}_C = \frac{\mathbf{Z}'\mathbf{I}_T}{\mathbf{Z}' + \mathbf{Z}_3} = \frac{(1.79\text{ k}\Omega\ \angle 26.57^\circ)(51.54\text{ mA}\ \angle 14.04^\circ)}{1.6\text{ k}\Omega + j0.8\text{ k}\Omega - j4\text{ k}\Omega}$$
$$= \mathbf{25.77\text{ mA}\ \angle 104.04^\circ}$$

CHAPTER 18 (Even)

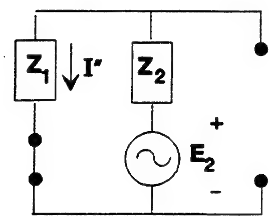
2. a. $\mathbf{E}_1$:



$\mathbf{E}_1 = 20\text{ V}\angle 0°,\ \mathbf{Z}_1 = 4\ \Omega + j3\ \Omega = 5\ \Omega\angle 36.87°$
$\mathbf{Z}_2 = 1\ \Omega\angle 0°$

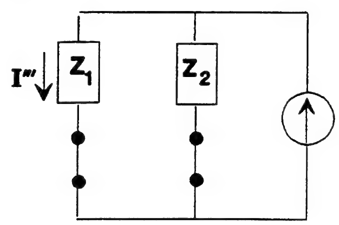
$$\mathbf{I}' = \frac{\mathbf{E}_1}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{20\text{ V}\angle 0°}{4\ \Omega + j3\ \Omega + 1\ \Omega} = 3.43\text{ A}\angle -30.96°$$

$\mathbf{E}_2$:



$$\mathbf{I}'' = \frac{\mathbf{E}_2}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{120\text{ V}\angle 0°}{5.83\ \Omega\angle 30.96°} = 20.58\text{ A}\angle -30.96°$$

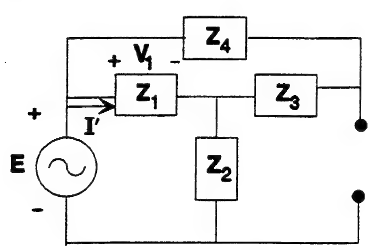
$\mathbf{I}$:



$$\mathbf{I}''' = \frac{\mathbf{Z}_2\mathbf{I}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(1\ \Omega\angle 0°)(0.5\text{ A}\angle 60°)}{5.83\ \Omega\angle 30.96°} = 0.0858\text{ A}\angle 29.04°$$

$\uparrow\mathbf{I}_L = \mathbf{I}' - \mathbf{I}'' - \mathbf{I}'''$
$= (3.43\text{ A}\angle -30.96°) - (20.58\text{ A}\angle -30.96°) - (0.0858\text{ A}\angle 29.04°)$
$= \mathbf{17.20\text{ A}\angle 149.30°}$ or $\mathbf{17.20\text{ A}\angle -30.70°}\downarrow$

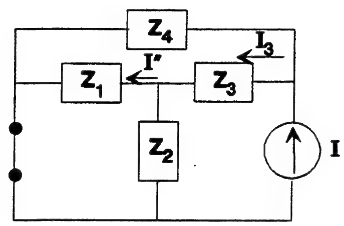
b. $\mathbf{E}$:



$\mathbf{Z}_1 = 3\ \Omega\angle 90°,\ \mathbf{Z}_2 = 7\ \Omega\angle -90°$
$\mathbf{E} = 10\text{ V}\angle 90°$
$\mathbf{Z}_3 = 6\ \Omega\angle -90°,\ \mathbf{Z}_4 = 4\ \Omega\angle 0°$
$\mathbf{Z}' = \mathbf{Z}_1 \| (\mathbf{Z}_3 + \mathbf{Z}_4)$
$= 3\ \Omega\angle 90° \| (4\ \Omega - j6\ \Omega)$
$= 3\ \Omega\angle 90° \| 7.21\ \Omega\angle -56.31°$
$= 4.33\ \Omega\angle 70.56°$

$$\mathbf{V}_1 = \frac{\mathbf{Z}'\mathbf{E}}{\mathbf{Z}' + \mathbf{Z}_2}$$
$$= \frac{(4.33\ \Omega\ \angle 70.56°)(10\ \text{V}\ \angle 90°)}{(1.44\ \Omega + j4.08\ \Omega) - j7\Omega}$$
$$= \frac{43.3\ \text{V}\ \angle 160.56°}{3.26\ \angle -63.75°} = 13.28\ \text{V}\ \angle 224.31°$$
$$\mathbf{I}' = \frac{\mathbf{V}_1}{\mathbf{Z}_1} = \frac{13.28\ \text{V}\ \angle 224.31°}{3\ \Omega\ \angle 90°}$$
$$= 4.43\ \text{A}\ \angle 134.31°$$

I:

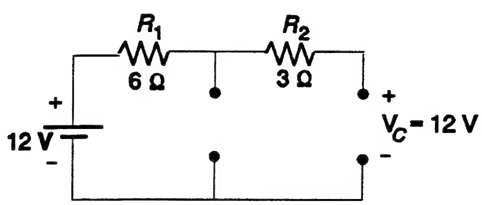


$$\mathbf{Z}'' = \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2$$
$$= -j6\ \Omega + 3\ \Omega\ \angle 90° \parallel 7\ \Omega\ \angle -90°$$
$$= -j6\ \Omega + 5.25\ \Omega\ \angle 90°$$
$$= -j6\ \Omega + j5.25\ \Omega$$
$$= -j0.75\ \Omega = 0.75\ \Omega \angle -90°$$

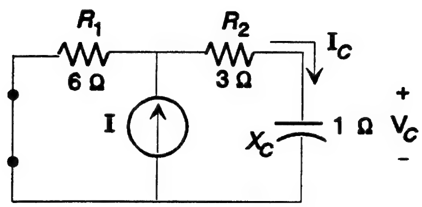
CDR: $$\mathbf{I}_3 = \frac{\mathbf{Z}_4\mathbf{I}}{\mathbf{Z}_4 + \mathbf{Z}''} = \frac{(4\ \Omega\ \angle 0°)(0.6\ \text{A}\ \angle 120°)}{4\ \Omega - j0.75\ \Omega} = \frac{2.4\ \text{A}\ \angle 120°}{4.07\ \angle -10.62°}$$
$$= 0.59\ \text{A}\ \angle 130.62°$$
$$\mathbf{I}'' = \frac{\mathbf{Z}_2\mathbf{I}_3}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(7\ \Omega\ \angle -90°)(0.59\ \text{A}\ \angle 130.62°)}{-j7\ \Omega + j3\ \Omega} = \frac{4.13\ \text{A}\ \angle 40.62°}{4\ \angle -90°}$$
$$= 1.03\ \text{A}\ \angle 130.62°$$

$\mathbf{I}_L = \mathbf{I}' - \mathbf{I}''$ (direction of $\mathbf{I}'$)
$$= 4.43\ \text{A}\ \angle 134.31° - 1.03\ \text{A}\ \angle 130.62°$$
$$= (-3.09\ \text{A} + j3.17\ \text{A}) - (-0.67\ \text{A} + j0.78\ \text{A}) = -2.42\ \text{A} + j2.39\ \text{A}$$
$$= \mathbf{3.40\ A\ \angle 135.36°}$$

4. DC:



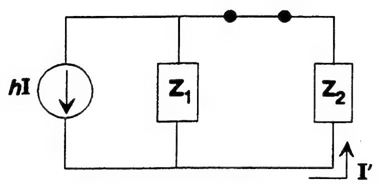
AC:



$$\mathbf{I}_C = \frac{(6\ \Omega\ \angle 0°)(\mathbf{I})}{6\ \Omega + 3\ \Omega - j1\ \Omega}$$
$$= \frac{(6\ \Omega\ \angle 0°)(4\ \text{A}\ \angle 0°)}{9\ \Omega - j1\ \Omega}$$
$$= \frac{24\ \text{A}\ \angle 0°}{9.055 \angle -6.34°}$$
$$= 2.65\ \text{A}\ \angle 6.34°$$

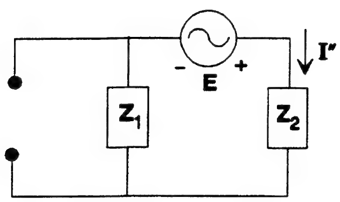
$$\mathbf{V}_C = \mathbf{I}_C\mathbf{X}_C = (2.65\ \text{A}\ \angle 6.34°)(1\ \Omega\ \angle -90°) = 2.65\ \text{V}\ \angle -83.66°$$
$$= \mathbf{12\ V + 2.65\ V\ \angle -83.66°}$$
$$v_C = \mathbf{12\ V + 3.747\ sin(\omega t - 83.66°)}$$

6.



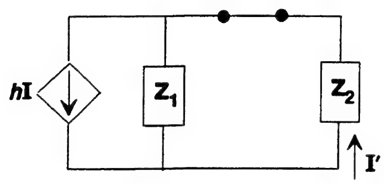
$Z_1 = 20\text{ k}\Omega \angle 0°$
$Z_2 = 10\text{ k}\Omega \angle 90°$
$I = 2\text{ mA} \angle 0°$
$E = 10\text{ V} \angle 0°$

$$I' = \frac{Z_1(hI)}{Z_1 + Z_2} = \frac{(20\text{ k}\Omega \angle 0°)(100)(2\text{ mA} \angle 0°)}{20\text{ k}\Omega + j10\text{ k}\Omega} = 0.179\text{ A} \angle -26.57°$$



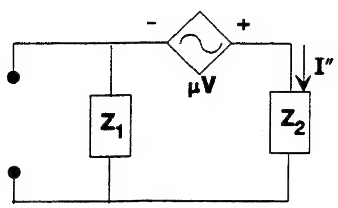
$$I'' = \frac{E}{Z_1 + Z_2} = \frac{10\text{ V} \angle 0°}{22.36\text{ k}\Omega \angle 26.57°}$$
$= 0.447\text{ mA} \angle -26.57°$
$I_L = I' - I''$ (direction of I')
$= 179\text{ mA} \angle -26.57° - 0.447\text{ mA} \angle -26.57°$
$= \mathbf{178.55\text{ mA} \angle -26.57°}$

8.



$Z_1 = 20\text{ k}\Omega \angle 0°$
$Z_2 = 5\text{ k}\Omega + j5\text{ k}\Omega$

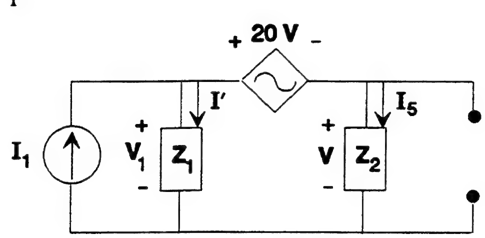
$$I' = \frac{Z_1(hI)}{Z_1 + Z_2} = \frac{(20\text{ k}\Omega \angle 0°)(100)(1\text{ mA} \angle 0°)}{20\text{ k}\Omega + 5\text{ k}\Omega + j5\text{ k}\Omega} = 78.45\text{ mA} \angle -11.31°$$



$$I'' = \frac{\mu V}{Z_1 + Z_2} = \frac{(20)(10\text{ V} \angle 0°)}{25.495\text{ k}\Omega \angle 11.31°}$$
$= 7.845\text{ mA} \angle -11.31°$

$I_L = I' - I''$ (direction of I')
$= 78.45\text{ mA} \angle -11.31° - 7.845\text{ mA} \angle -11.31°$
$= \mathbf{70.61\text{ mA} \angle -11.31°}$

10. I_1:



$I_1 = 1\text{ mA} \angle 0°$
$Z_1 = 2\text{ k}\Omega \angle 0°$
$Z_2 = 5\text{ k}\Omega \angle 0°$

KVL: $V_1 - 20\text{ V} - V = 0$ $\quad I' = \dfrac{V_1}{Z_1} \therefore I' = \dfrac{21\text{ V}}{Z_1}$ or $V = \dfrac{Z_1}{21}I'$

$V_1 = 21\text{ V}$

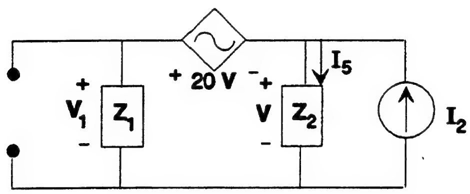
$$\mathbf{V} = \mathbf{I}_5\mathbf{Z}_2 = [\mathbf{I}_1 - \mathbf{I}']\mathbf{Z}_2$$

$$\frac{\mathbf{Z}_1}{21}\mathbf{I}' = \mathbf{I}_1\mathbf{Z}_2 - \mathbf{I}'\mathbf{Z}_2$$

$$\mathbf{I}'\left[\frac{\mathbf{Z}_1}{21} + \mathbf{Z}_2\right] = \mathbf{I}_1\mathbf{Z}_2$$

$$\text{and } \mathbf{I}' = \frac{\mathbf{Z}_2}{\dfrac{\mathbf{Z}_1}{21} + \mathbf{Z}_2}[\mathbf{I}_1] = \frac{(5\text{ k}\Omega\ \angle 0^\circ)(1\text{ mA}\ \angle 0^\circ)}{\left[\dfrac{2\text{ k}\Omega\ \angle 0^\circ}{21}\right] + 5\text{ k}\Omega\ \angle 0^\circ} = 0.981\text{ mA}\ \angle 0^\circ$$

$\mathbf{I}_2$:



$$\mathbf{V}_1 = 20\text{ V} + \mathbf{V} = 21\text{ V}$$

$$\mathbf{I}'' = \frac{\mathbf{V}_1}{\mathbf{Z}_1} = \frac{21\text{ V}}{\mathbf{Z}_1} \Rightarrow \mathbf{V} = \frac{\mathbf{Z}_1}{21}\mathbf{I}''$$

$$\mathbf{I}_5 = \frac{\mathbf{V}}{\mathbf{Z}_2} = \frac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}\mathbf{I}''$$

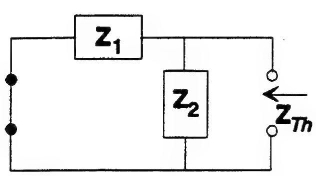
$$\mathbf{I}'' = \mathbf{I}_2 - \mathbf{I}_5 = \mathbf{I}_2 - \frac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}\mathbf{I}''$$

$$\mathbf{I}''\left[1 + \frac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}\right] = \mathbf{I}_2$$

$$\mathbf{I}'' = \frac{\mathbf{I}_2}{1 + \dfrac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}} = \frac{2\text{ mA}\ \angle 0^\circ}{1 + \dfrac{2\text{ k}\Omega}{21(5\text{ k}\Omega)}} = 1.963\text{ mA}\ \angle 0^\circ$$

$$\begin{aligned}\mathbf{I} = \mathbf{I}' + \mathbf{I}'' &= 0.981\text{ mA}\ \angle 0^\circ + 1.963\text{ mA}\ \angle 0^\circ \\ &= \mathbf{2.944\ mA\ \angle 0^\circ}\end{aligned}$$

12. a. $\mathbf{Z}_{Th}$:

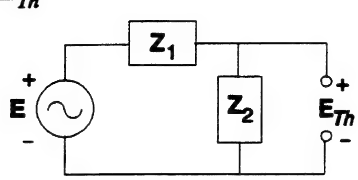


$\mathbf{Z}_1 = 3\ \Omega\ \angle 0^\circ$, $\mathbf{Z}_2 = 4\ \Omega\ \angle 90^\circ$

$\mathbf{E} = 100\text{ V}\ \angle 0^\circ$

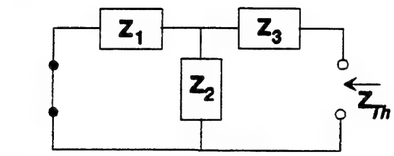
$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_1 \| \mathbf{Z}_2 = (3\ \Omega\ \angle 0^\circ \| 4\ \Omega\ \angle 90^\circ) \\ &= 2.4\ \Omega\ \angle 36.87^\circ = 1.92\ \Omega + j1.44\ \Omega\end{aligned}$$

$\mathbf{E}_{Th}$:



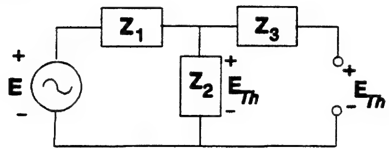
$$\begin{aligned}\mathbf{E}_{Th} &= \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(4\ \Omega\ \angle 90^\circ)(100\text{ V}\ \angle 0^\circ)}{5\ \Omega\ \angle 53.13^\circ} \\ &= \mathbf{80\ V\ \angle 36.87^\circ}\end{aligned}$$

b. $\mathbf{Z}_{Th}$:



$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2 \\ &= +j6\text{ k}\Omega + (2\text{ k}\Omega\ \angle 0° \| 3\text{ k}\Omega\ \angle -90°) \\ &= +j6\text{ k}\Omega + 1.664\text{ k}\Omega\ \angle -33.69° \\ &= +j6\text{ k}\Omega + 1.385\text{ k}\Omega - j0.923\text{ k}\Omega \\ &= 1.385\text{ k}\Omega + j5.077\text{ k}\Omega \\ &= \mathbf{5.263\text{ k}\Omega\ \angle 74.741°}\end{aligned}$$

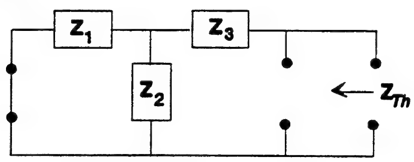
$\mathbf{E}_{Th}$:



$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(3\text{ k}\Omega\ \angle -90°)(20\text{ V}\ \angle 0°)}{2\text{ k}\Omega - j3\text{ k}\Omega}$$

$$= \frac{60\text{ V}\ \angle -90°}{3.606\ \angle -56.31°} = \mathbf{16.639\text{ V}\ \angle -33.69°}$$

14. a. $\mathbf{Z}_{Th}$:

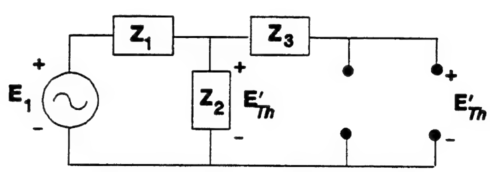


$\mathbf{Z}_1 = 10\ \Omega\ \angle 0°$, $\mathbf{Z}_2 = 8\ \Omega\ \angle 90°$
$\mathbf{Z}_3 = 8\ \Omega\ \angle -90°$

$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2 \\ &= -j8\ \Omega + 10\ \Omega\ \angle 0° \| 8\ \Omega\ \angle 90° \\ &= -j8\ \Omega + 6.247\ \Omega\ \angle 51.34° \\ &= -j8\ \Omega + 3.902\ \Omega + j4.878\ \Omega \\ &= 3.902\ \Omega - j3.122\ \Omega \\ &= \mathbf{4.997\ \Omega\ \angle -38.663°}\end{aligned}$$

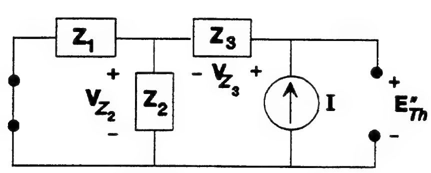
$\mathbf{E}_{Th}$: Superposition:

($\mathbf{E}_1$)



$$\begin{aligned}\mathbf{E}'_{Th} &= \frac{(8\ \Omega\ \angle 90°)(120\text{ V}\ \angle 0°)}{10\ \Omega + j8\ \Omega} \\ &= \frac{960\text{ V}\ \angle 90°}{12.806\ \angle 38.66°} \\ &= 74.965\text{ V}\ \angle 51.34°\end{aligned}$$

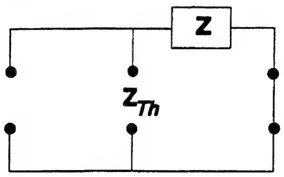
(I)



$$\begin{aligned}\mathbf{E}''_{Th} &= \mathbf{V}_{Z_2} + \mathbf{V}_{Z_3} \\ &= \mathbf{I}\mathbf{Z}_3 + \mathbf{I}(\mathbf{Z}_1 \| \mathbf{Z}_2) \\ &= \mathbf{I}(\mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2) \\ &= (0.5\text{ A}\ \angle 60°)(-j8\ \Omega + 10\ \Omega\ \angle 0° \| 8\ \Omega\ \angle 90°) \\ &= (0.5\text{ A}\ \angle 60°)(-j8\ \Omega + 3.902\ \Omega + j4.878\ \Omega) \\ &= (0.5\text{ A}\ \angle 60°)(3.902\ \Omega - j3.122\ \Omega) \\ &= (0.5\text{ A}\ \angle 60°)(4.997\ \Omega\ \angle -38.663°) \\ &= 2.499\text{ V}\ \angle 21.337°\end{aligned}$$

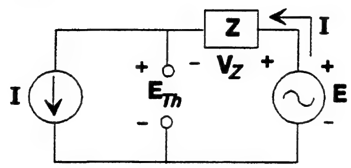
$$\begin{aligned}\mathbf{E}_{Th} &= \mathbf{E}'_{Th} + \mathbf{E}''_{Th} \\ &= 74.965\text{ V } \angle 51.34° + 2.449\text{ V } \angle 21.337° \\ &= (46.83\text{ V} + j58.538\text{ V}) + (2.328\text{ V} + j0.909\text{ V}) \\ &= 49.158\text{ V} + j59.447\text{ V} = \mathbf{77.139\ V\ \angle 50.412°}\end{aligned}$$

b. $\mathbf{Z}_{Th}$:



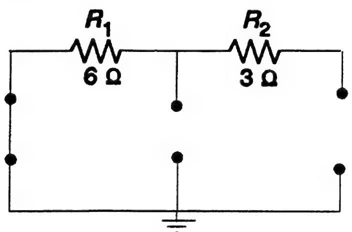
$$\mathbf{Z}_{Th} = \mathbf{Z} = 10\ \Omega - j10\ \Omega = 14.142\ \Omega\ \angle -45°$$

$\mathbf{E}_{Th}$:



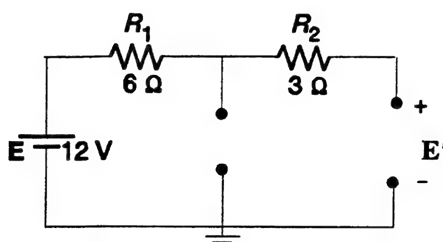
$$\begin{aligned}\mathbf{E}_{Th} &= \mathbf{E} - \mathbf{V}_Z \\ &= 20\text{ V } \angle 40° - \mathbf{IZ} \\ &= 20\text{ V } \angle 40° - (0.6\text{ A } \angle 90°)(14.142\ \Omega\ \angle -45°) \\ &= 20\text{ V } \angle 40° - 8.485\text{ V } \angle 45° \\ &= (15.321\text{ V} + j12.856\text{ V}) - (6\text{ V} + j6\text{ V}) \\ &= 9.321\text{ V} + j6.856\text{ V} \\ &= \mathbf{11.571\ V\ \angle 36.336°}\end{aligned}$$

16. a. $\mathbf{Z}_{Th}$:



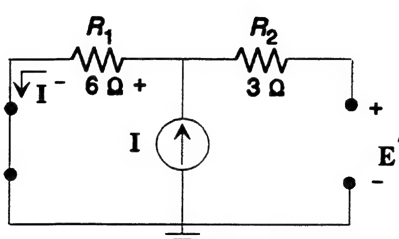
$$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_{R_1} + \mathbf{Z}_{R_2} = 6\ \Omega + 3\ \Omega = \mathbf{9\ \Omega}$$

DC:



$$\mathbf{E}'_{Th} = 12\text{ V}$$

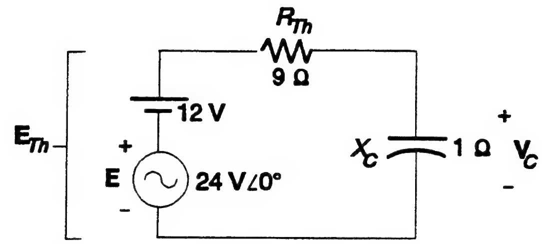
AC:



$$\mathbf{E}''_{Th} = \mathbf{IZ}_{R_1} = (4\text{ A } \angle 0°)(6\ \Omega\ \angle 0°) = 24\text{ V } \angle 0°$$

$$\mathbf{E}_{Th} = \underset{\text{(DC)}}{12\text{ V}} + \underset{\text{(AC)}}{24\text{ V } \angle 0°}$$

b.



DC: $\mathbf{V}_C = 12\text{ V}$

AC: $\mathbf{V}_C = \dfrac{\mathbf{Z}_C\mathbf{E}}{\mathbf{Z}_C + \mathbf{Z}_{R_{Th}}}$

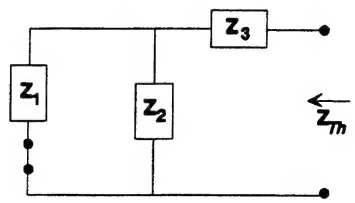
$= \dfrac{(1\ \Omega\ \angle -90°)(24\text{ V}\ \angle 0°)}{-j1\ \Omega + 9\ \Omega}$

$= \dfrac{24\text{ V}\angle -90°}{9.055\ \angle -6.34°}$

$\mathbf{V}_C = 2.65\text{ V}\ \angle -83.66°$

$v_C = 12\text{ V} + 2.65\text{ V}\ \angle -83.66°$
$= \mathbf{12\ V + 3.747\ sin(\omega t - 83.66°)}$

18.

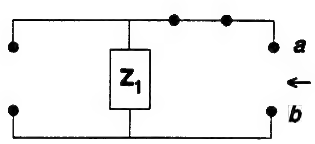


$\mathbf{Z}_1 = 10\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 10\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_3 = 1\text{ k}\Omega\ \angle -90°$

$\mathbf{Z}_{Th} = \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2 = 5\text{ k}\Omega - j1\text{ k}\Omega \cong \mathbf{5.1\ k\Omega\ \angle -11.31°}$

$\mathbf{E}_{Th}$: (VDR) $\qquad \mathbf{E}_{Th} = \dfrac{\mathbf{Z}_2(20\text{ V})}{\mathbf{Z}_2 + \mathbf{Z}_1} = \dfrac{(10\text{ k}\Omega\ \angle 0°)(20)\text{V}}{10\text{ k}\Omega + 10\text{ k}\Omega} = \mathbf{10\ V}$

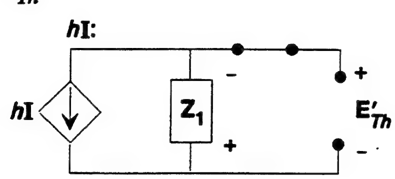
20. $\mathbf{Z}_{Th}$:



$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 = \mathbf{20\ k\Omega\ \angle 0°}$

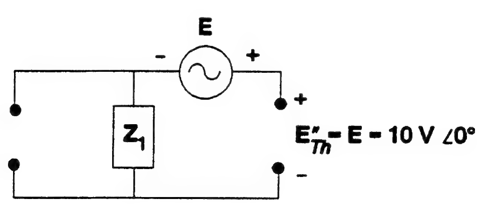
$\mathbf{E}_{Th}$:

*h*I:



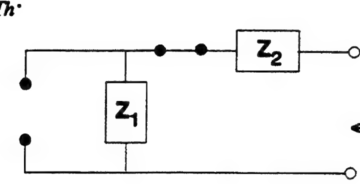
$\mathbf{E}'_{Th} = -(h\mathbf{I})(\mathbf{Z}_1)$
$= -(100)(2\text{ mA}\ \angle 0°)(20\text{ k}\Omega\ \angle 0°)$
$= -4\text{ kV}\ \angle 0°$

E:



$\mathbf{E}_{Th} = \mathbf{E}'_{Th} + \mathbf{E}''_{Th}$
$= -4\text{ kV}\ \angle 0° + 10\text{ V}\ \angle 0°$
$= \mathbf{-3990\ V\ \angle 0°}$

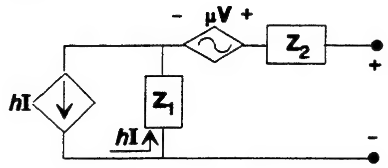
22. $\mathbf{Z}_{Th}$:



$\mathbf{Z}_1 = 20\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\text{ k}\Omega\ \angle 0°$

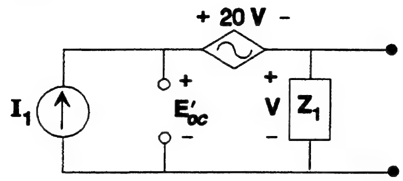
$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 + \mathbf{Z}_2 = \mathbf{25\ k\Omega\ \angle 0°}$

$\mathbf{E}_{Th}$:



$$\mathbf{E}_{Th} = \mu\mathbf{V} - (h\mathbf{I})(\mathbf{Z}_1)$$
$$= (20)(10\text{ V}\angle 0°) - (100)(1\text{ mA}\angle 0°)(20\text{ k}\Omega\angle 0°)$$
$$= \mathbf{-1800\text{ V}\angle 0°}$$

24. $\mathbf{E}_{Th}$:



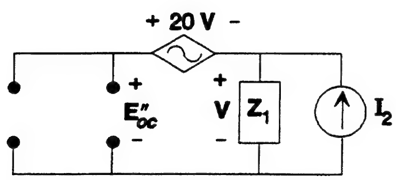
$\mathbf{E}'_{oc} = 21\text{ V} \qquad \mathbf{Z}_1 = 5\text{ k}\Omega\angle 0°$

$\mathbf{V} = \mathbf{I}_1\mathbf{Z}_1 = (1\text{ mA}\angle 0°)(5\text{ k}\Omega\angle 0°)$

$= 5\text{ V}\angle 0°$

$\mathbf{E}'_{oc} = \mathbf{E}'_{Th} = 21(5\text{ V}\angle 0°)$

$= 105\text{ V}\angle 0°$



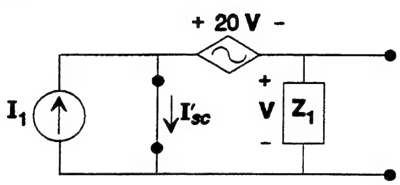
$\mathbf{V} = \mathbf{I}_2\mathbf{Z}_1$

$= (2\text{ mA}\angle 0°)(5\text{ k}\Omega\angle 0°)$

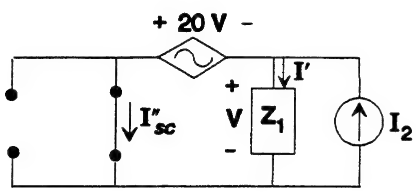
$= 10\text{ V}\angle 0°$

$\mathbf{E}''_{oc} = \mathbf{E}''_{Th} = 21\text{ V} = 210\ V\angle 0°$

$\mathbf{I}_{sc}$:



$\mathbf{I}'_{sc} = \mathbf{I}_1$



$20\text{ V} = \mathbf{V} \therefore \mathbf{V} = 0\text{ V}$

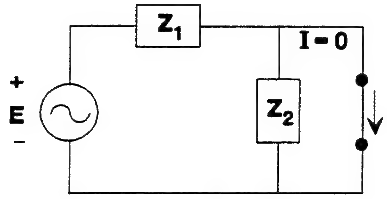
and $\mathbf{I}' = 0\text{ A}$

$\therefore\ \mathbf{I}''_{sc} = \mathbf{I}_2$

$$\mathbf{I}_{sc} = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = 3\text{ mA}\angle 0°$$
$$\mathbf{E}_{oc} = \mathbf{E}'_{oc} + \mathbf{E}''_{oc} = 315\text{ V}\angle 0° = \mathbf{E}_{Th}$$
$$\mathbf{Z}_{Th} = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{315\text{ V}\angle 0°}{3\text{ mA}\angle 0°} = \mathbf{105\text{ k}\Omega\angle 0°}$$

26. a. From Problem 12(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = 1.92\ \Omega + j1.44\ \Omega = \mathbf{2.4\ \Omega\ \angle 36.87°}$

$\mathbf{I}_N$:

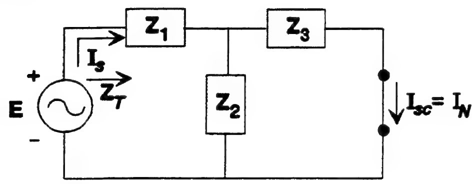


$\mathbf{Z}_1 = 3\ \Omega\ \angle 0°,\ \mathbf{Z}_2 = 4\ \Omega\ \angle 90°$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{E}}{\mathbf{Z}_1} = \frac{100\ \text{V}\ \angle 0°}{3\ \Omega\ \angle 0°} = \mathbf{33.33\ A\ \angle 0°}$$

b. From Problem 12(b): $\mathbf{Z}_N = \mathbf{Z}_{Th} = 5.263\ \text{k}\Omega\ \angle 74.741° = \mathbf{1.385\ k\Omega + j6.923\ k\Omega}$

$\mathbf{I}_N$:



$\mathbf{Z}_1 = 2\ \text{k}\Omega\ \angle 0°,\ \mathbf{Z}_2 = 3\ \text{k}\Omega\ \angle -90°$
$\mathbf{Z}_3 = 6\ \text{k}\Omega \angle 90°$

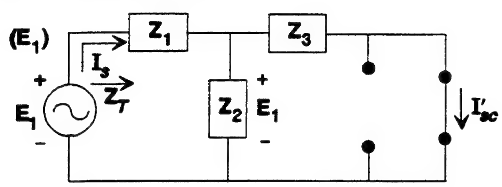
$$\begin{aligned}\mathbf{Z}_T &= \mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3 \\ &= 2\ \text{k}\Omega + 3\ \text{k}\Omega\ \angle -90° \| 6\ \text{k}\Omega\ \angle 90° \\ &= 2\ \text{k}\Omega + 6\ \text{k}\Omega\ \angle -90° \\ &= 2\ \text{k}\Omega - j6\ \text{k}\Omega \\ &= 6.325\ \text{k}\Omega\ \angle -71.565°\end{aligned}$$

$$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{20\ \text{V}\ \angle 0°}{6.325\ \text{k}\Omega\ \angle -71.565°} = 3.162\ \text{mA}\ \angle 71.565°$$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{Z}_2\mathbf{I}_s}{\mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(3\ \text{k}\Omega\ \angle -90°)(3.162\text{mA}\ \angle 71.565°)}{-j3\ \text{k}\Omega + j6\ \text{k}\Omega}$$
$$= \frac{9.486\ \text{mA}\ \angle -18.435°}{3\ \angle 90°} = \mathbf{3.162\ mA\ \angle -108.435°}$$

28. a. From Problem 14(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4.997\ \Omega\ \angle -38.663°}$

$\mathbf{I}_N$: Superposition:



$$\begin{aligned}\mathbf{Z}_T &= \mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3 \\ &= 10\ \Omega + 8\ \Omega\ \angle 90° \| 8\ \Omega\ \angle -90° \\ &= 10\ \Omega + \frac{64\ \Omega\ \angle 0°}{0} \\ &= \text{very large impedance}\end{aligned}$$

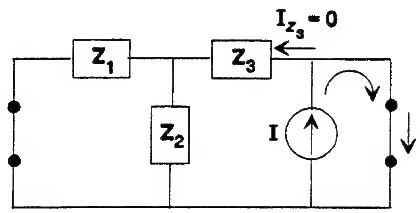
$$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = 0\ \text{A}$$

and $\mathbf{V}_{Z_1} = 0\ \text{V}$

with $\mathbf{V}_{Z_2} = \mathbf{V}_{Z_3} = \mathbf{E}_1 = 120\ \text{V}\ \angle 0°$

so that $$\mathbf{I'}_{sc} = \frac{\mathbf{E}_1}{\mathbf{Z}_3} = \frac{120\ \text{V}\ \angle 0°}{8\ \Omega\ \angle -90°} = 15\ \text{A}\ \angle 90°$$

(I)

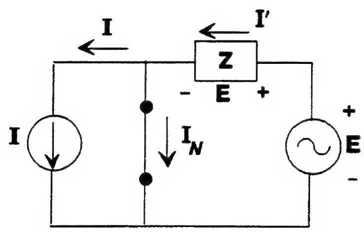


$\mathbf{I''}_{sc} = \mathbf{I} = 0.5 \text{ A } \angle 60°$

$$\mathbf{I}_N = \mathbf{I'}_{sc} + \mathbf{I''}_{sc} = +j15 \text{ A} + 0.5 \text{ A } \angle 60° = +j15 \text{ A} + 0.25 \text{ A} + j0.433 \text{ A}$$
$$= 0.25 \text{ A} + j15.433 \text{ A} = \mathbf{15.435 \text{ A } \angle 89.072°}$$

b. From Problem 14(b): $\mathbf{Z}_N = \mathbf{Z}_{Th} = 10 \ \Omega - j10 \ \Omega = \mathbf{14.142 \ \Omega \angle -45°}$

$\mathbf{I}_N$:

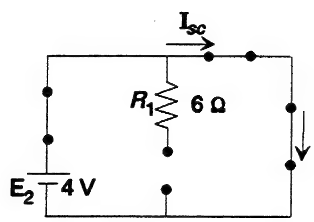


$$\mathbf{I}_N = \mathbf{I'} - \mathbf{I}$$
$$= \frac{\mathbf{E}}{\mathbf{Z}} - \mathbf{I}$$
$$= \frac{20 \text{ V } \angle 40°}{14.142 \ \Omega \ \angle -45°} - 0.6 \text{ A } \angle 90°$$
$$= 1.414 \text{ A } \angle 85° - j0.6 \text{ A}$$
$$= 0.123 \text{ A} + j1.409 \text{ A} - j0.6 \text{ A}$$
$$= 0.123 \text{ A} + j0.809 \text{ A}$$
$$= \mathbf{0.818 \text{ A } \angle 81.355°}$$

30. a. Note Problem 15(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4 \ \Omega \angle 90°}$

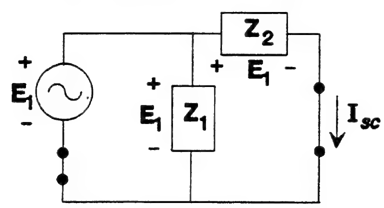
$\mathbf{I}_N$:

DC



$$\mathbf{I}_{sc} = \frac{E_2}{0 \ \Omega} = \frac{4 \text{ V}}{0 \ \Omega}$$

AC

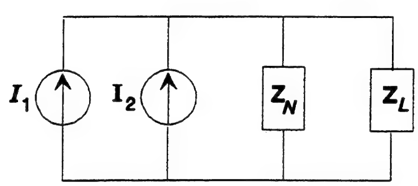


$\mathbf{Z}_1 = 6 \ \Omega - j2 \ \Omega$
$\mathbf{Z}_2 = 4 \ \Omega \angle 90°$

$$\mathbf{I}_{sc} = \frac{\mathbf{E}_1}{\mathbf{Z}_2} = \frac{10 \text{ V } \angle 0°}{4 \ \Omega \ \angle 90°} = 2.5 \text{ A } \angle -90°$$

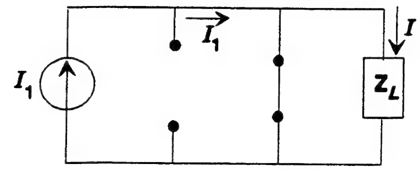
$$\mathbf{I}_N = \frac{4 \text{ V}}{0 \ \Omega} + 2.5 \text{ A } \angle -90° \quad \left(\text{dc: } \mathbf{E}_{Th} = I_N Z_N = \frac{4 \text{ V}}{(0 \ \Omega)}(0 \ \Omega) = 4 \text{ V}\right)$$

b.



$\mathbf{Z}_N = 4 \ \Omega \angle 90°$
$\mathbf{Z}_L = 8 \ \Omega \angle 0°$

DC:



(CDR)

$$I = \frac{(0\ \Omega)I_1}{0\ \Omega + 8\ \Omega}$$

$$= \frac{(0\ \Omega)\left[\dfrac{4\ \text{V}}{0\ \Omega}\right]}{0\ \Omega + 8\ \Omega} = \frac{4\ \text{V}}{8\ \Omega} = 0.5\ \text{A}$$

as obtained in Problem 15

AC:

$$\mathbf{I} = \frac{\mathbf{Z}_N(\mathbf{I}_2)}{\mathbf{Z}_N + \mathbf{Z}_L} = \frac{(4\ \Omega\ \angle 90°)(2.5\ \text{A}\ \angle -90°)}{+j4\ \Omega + 8\ \Omega}$$

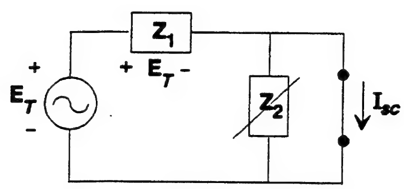
$$= \frac{10\ \text{V}\ \angle 0°}{8.944\ \Omega\ \angle 26.565°} = \mathbf{1.118\ A\ \angle -26.565°} \text{ as obtained in Problem 15}$$

$$I_{8\Omega} = \underset{\text{(dc)}}{0.5\ \text{A}} + \underset{\text{(ac)}}{1.118\ \text{A}\ \angle -26.565°}$$

32. a. Note Problem 17(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4.472\ k\Omega\ \angle -26.565°}$

Using the same source conversion: $\mathbf{E}_1 = 50\ \text{V}\ \angle 0°$

Defining $\mathbf{E}_T = \mathbf{E}_1 + \mathbf{E} = 50\ \text{V}\ \angle 0° + 20\ \text{V}\ \angle 0° = 70\ \text{V}\ \angle 0°$



$\mathbf{Z}_1 = 10\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\ \text{k}\Omega - j5\ \text{k}\Omega = 7.071\ \text{k}\Omega\ \angle -45°$

$$\mathbf{I}_{sc} = \frac{\mathbf{E}_T}{\mathbf{Z}_1} = \frac{70\ \text{V}\ \angle 0°}{10\ \text{k}\Omega\ \angle 0°} = 7\ \text{mA}\ \angle 0°$$

$\mathbf{I}_N = \mathbf{I}_{sc} = \mathbf{7\ mA\ \angle 0°}$

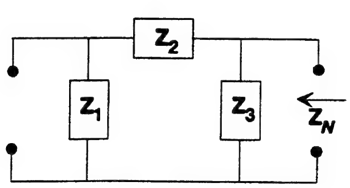
b.

$$\mathbf{I} = \frac{\mathbf{Z}_N(\mathbf{I}_N)}{\mathbf{Z}_N + \mathbf{Z}_L} = \frac{(4.472\ \text{k}\Omega\ \angle -26.565°)(7\ \text{mA}\ \angle 0°)}{4.472\ \text{k}\Omega\ \angle -26.565° + 5\ \text{k}\Omega\ \angle 90°}$$

$$= \frac{31.30\ \text{mA}\ \angle -26.565°}{4 - j2 + j5} = \frac{31.30\ \text{mA}\ \angle -26.565°}{4 + j3}$$

$$= \frac{31.30\ \text{mA}\ \angle -26.565°}{5\ \angle 36.87°} = 6.26\ \text{mA}\ \angle 63.435° \text{ as obtained in Problem 17.}$$

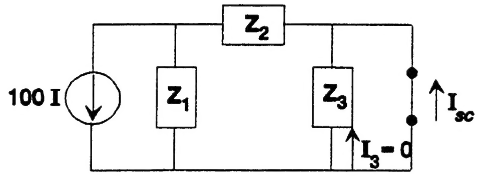
34. $\mathbf{Z}_N$:



$\mathbf{Z}_1 = 40\ \text{k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 0.2\ \text{k}\Omega\ \angle -90°$
$\mathbf{Z}_3 = 5\ \text{k}\Omega\ \angle 0°$

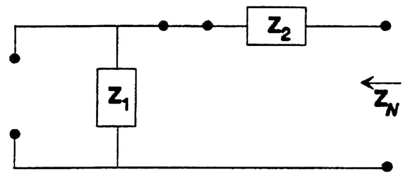
$$\mathbf{Z}_N = \mathbf{Z}_3 \| (\mathbf{Z}_1 + \mathbf{Z}_2)$$
$$= 5\ \text{k}\Omega\ \angle 0° \| (40\ \text{k}\Omega - j0.2\ \text{k}\Omega)$$
$$= \mathbf{4.44\ k\Omega\ \angle -0.031°}$$

$\mathbf{I}_N$:



$$\mathbf{I}_N = \mathbf{I}_{sc} = \frac{\mathbf{Z}_1(100\ \mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2}$$
$$= \frac{(40\ \text{k}\Omega\ \angle 0°)(100\ \mathbf{I})}{40\ \text{k}\Omega\ \angle -0.286°}$$
$$= \mathbf{100\ I\ \angle 0.286°}$$

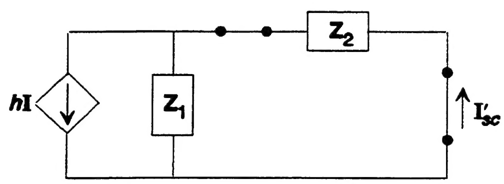
36. $\mathbf{Z}_N$:



$\mathbf{Z}_1 = 20\ \text{k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 5\ \text{k}\Omega\ \angle 0°$
$\mathbf{V} = 10\ \text{V}\ \angle 0°$, $\mu = 20$, $h = 100$
$\mathbf{I} = 1\ \text{mA}\ \angle 0°$

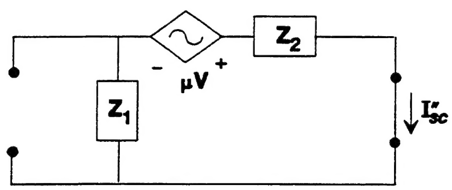
$$\mathbf{Z}_N = \mathbf{Z}_1 + \mathbf{Z}_2 = \mathbf{25\ k\Omega\ \angle 0°}$$

$\mathbf{I}_N$: $(h\mathbf{I})$



$$\mathbf{I}'_{sc} = \frac{\mathbf{Z}_1(h\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2}$$
$$= \frac{(20\ \text{k}\Omega\ \angle 0°)(h\mathbf{I})}{20\ \text{k}\Omega\ \angle 0° + 5\ \text{k}\Omega\ \angle 0°}$$
$$= 80\ \text{mA}\ \angle 0°$$

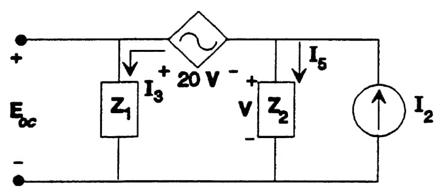
$(\mu\mathbf{V})$



$$\mathbf{I}''_{sc} = \frac{\mu\mathbf{V}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20)(10\ \text{V}\ \angle 0°)}{25\ \text{k}\Omega}$$
$$= 8\ \text{mA}\ \angle 0°$$

$\mathbf{I}_N$ (direction of $\mathbf{I}'_{sc}$) $= \mathbf{I}'_{sc} - \mathbf{I}''_{sc} = 80\ \text{mA}\ \angle 0° - 8\ \text{mA}\ \angle 0° = \mathbf{72\ mA\ \angle 0°}$

38.

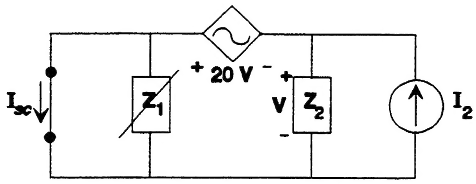


$\mathbf{Z}_1 = 2\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\ \text{k}\Omega\ \angle 0°$

$$\mathbf{I}_2 = \mathbf{I}_3 + \mathbf{I}_5$$
$$\mathbf{V} = \mathbf{I}_5\mathbf{Z}_2 = (\mathbf{I}_2 - \mathbf{I}_3)\mathbf{Z}_2$$
$$\mathbf{E}_{oc} = \mathbf{E}_{Th} = 21\ \mathbf{V} = 21(\mathbf{I}_2 - \mathbf{I}_3)\mathbf{Z}_2$$
$$= 21\left(\mathbf{I}_2 - \frac{\mathbf{E}_{oc}}{\mathbf{Z}_1}\right)\mathbf{Z}_2$$
$$\mathbf{E}_{oc}\left[1 + 21\frac{\mathbf{Z}_2}{\mathbf{Z}_1}\right] = 21\ \mathbf{Z}_2\mathbf{I}_2$$

$$\mathbf{E}_{oc} = \frac{21\ \mathbf{Z}_2\mathbf{I}_2}{1 + 21\ \dfrac{\mathbf{Z}_2}{\mathbf{Z}_1}} = \frac{21(5\ \text{k}\Omega\ \angle 0°)(2\ \text{mA}\ \angle 0°)}{1 + 21\left[\dfrac{5\ \text{k}\Omega\ \angle 0°}{2\ \text{k}\Omega\ \angle 0°}\right]}$$

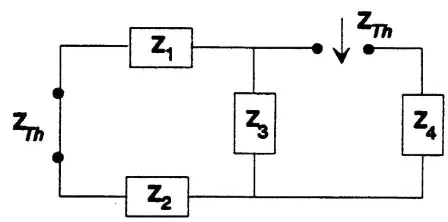
$$\mathbf{E}_{Th} = \mathbf{E}_{oc} = \mathbf{3.925\ V\ \angle 0°}$$



$20\ \text{V} \neq -\mathbf{V}\ \therefore\ \mathbf{V} = 0$
and $\mathbf{I}_{sc} = \mathbf{I}_2 = \mathbf{I}_N = \mathbf{2\ mA\ \angle 0°}$

$$\mathbf{Z}_N = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{3.925\ \text{V}\ \angle 0°}{2\ \text{mA}\ \angle 0°} = \mathbf{1.9625\ k\Omega}$$

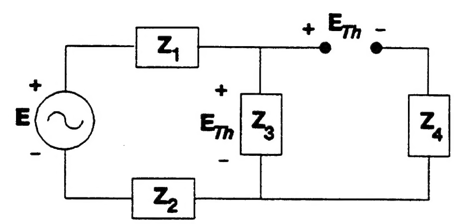
40. a. $\mathbf{Z}_{Th}$:



$\mathbf{Z}_1 = 4\ \Omega\ \angle 90°$, $\mathbf{Z}_2 = 10\ \Omega\ \angle 0°$
$\mathbf{Z}_3 = 5\ \Omega\ \angle -90°$, $\mathbf{Z}_4 = 6\ \Omega\ \angle -90°$
$\mathbf{E} = 60\ \text{V}\ \angle 60°$

$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_4 + \mathbf{Z}_3 \| (\mathbf{Z}_1 + \mathbf{Z}_2) = -j6\ \Omega + (5\ \Omega\ \angle -90°) \| (10\ \Omega + j4\ \Omega)\\ &= 2.475\ \Omega - j4.754\ \Omega\\ &= 11.035\ \Omega\ \angle -77.03°\\ \mathbf{Z}_L &= \mathbf{11.035\ \Omega\ \angle 77.03°}\end{aligned}$$

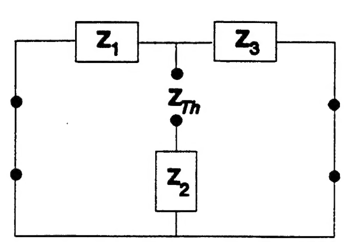
$\mathbf{E}_{Th}$:



$$\begin{aligned}\mathbf{E}_{Th} &= \frac{\mathbf{Z}_3(\mathbf{E})}{\mathbf{Z}_3 + \mathbf{Z}_1 + \mathbf{Z}_2}\\ &= \frac{(5\ \Omega\ \angle -90°)(60\ \text{V}\ \angle 60°)}{-j5\ \Omega + j4\ \Omega + 10\ \Omega}\\ &= \mathbf{29.85\ V\ \angle -24.29°}\end{aligned}$$

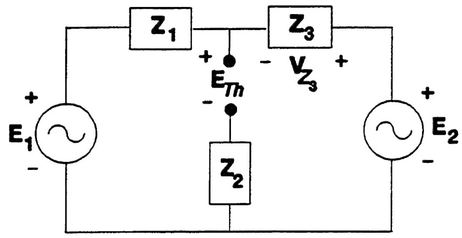
$$P_{\max} = E_{Th}^2/4R_{Th} = (29.85\ \text{V})^2/4(2.475\ \Omega) = \mathbf{90\ W}$$

b.



$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13°$
$\mathbf{Z}_2 = -j8\ \Omega$
$\mathbf{Z}_3 = 12\ \Omega + j9\ \Omega$

$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_2 + \mathbf{Z}_1 \| \mathbf{Z}_3 = -j8\ \Omega + (5\ \Omega\ \angle 53.13°) \| (15\ \Omega\ \angle 36.87°)\\ &= 5.71\ \Omega\ \angle -64.30° = 2.475\ \Omega - j5.143\ \Omega\\ \mathbf{Z}_L &= \mathbf{5.71\ \Omega\ \angle 64.30° = 2.475\ \Omega + j5.143\ \Omega}\end{aligned}$$



$$\mathbf{E}_{Th} + \mathbf{V}_{Z_3} - \mathbf{E}_2 = 0$$
$$\mathbf{E}_{Th} = \mathbf{E}_2 - \mathbf{V}_{Z_3}$$
$$\mathbf{V}_{Z_3} = \frac{\mathbf{Z}_3(\mathbf{E}_2 - \mathbf{E}_1)}{\mathbf{Z}_3 + \mathbf{Z}_1} = 168.97 \text{ V } \angle 112.53°$$

$$\mathbf{E}_{Th} = \mathbf{E}_2 - \mathbf{V}_{Z_3} = 200 \text{ V } \angle 90° - 168.97 \text{ V } \angle 112.53° = \mathbf{78.24\ V\ \angle 34.16°}$$
$$P_{max} = E_{Th}^2/4R_{Th} = (78.24 \text{ V})^2/4(2.475\ \Omega) = \mathbf{618.33\ W}$$

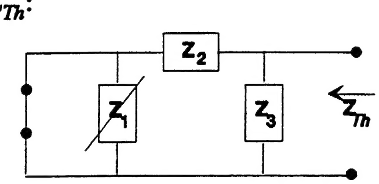
42. a. $\mathbf{Z}_{Th} = 4\ \Omega \angle 90°$ (Problem 15(a))
$\mathbf{Z}_L = \mathbf{4\ k\Omega\ \angle -90°}$

b. Since load purely reactive P_{max} undefined ($P_{max} = \dfrac{E_{Th}^2}{4R_{Th}}$, $R_{Th} = 0\ \Omega$)

44. a. Problem 17(a):
$\mathbf{Z}_{Th} = 4.472 \text{ k}\Omega \angle -26.565° = 4 \text{ k}\Omega - j2 \text{ k}\Omega$
$\mathbf{Z}_L = \mathbf{4\ k\Omega + \mathit{j}2\ k\Omega}$
$\mathbf{E}_{Th} = \mathbf{31.31\ V\ \angle -26.565°}$

b. $P_{max} = E_{Th}^2/4R_{Th} = (31.31 \text{ V})^2/4(4 \text{ k}\Omega) = \mathbf{61.27\ mW}$

46. a. $\mathbf{Z}_{Th}$:



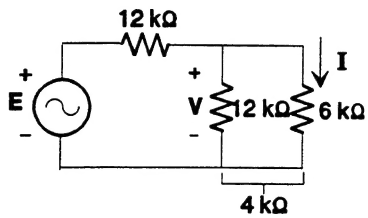
$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(10 \text{ kHz})(3.98 \text{ nF})} \cong 4 \text{ k}\Omega$$
$$X_L = 2\pi fL = 2\pi(10 \text{ kHz})(31.8 \text{ mH}) \cong 2 \text{ k}\Omega$$
$\mathbf{Z}_1 = 1 \text{ k}\Omega \angle 0°$, $\mathbf{Z}_2 = 2 \text{ k}\Omega \angle 90°$
$\mathbf{Z}_3 = 4 \text{ k}\Omega \angle -90°$

$\mathbf{Z}_{Th} = \mathbf{Z}_2 \| \mathbf{Z}_3 = (2 \text{ k}\Omega \angle 90°) \| (4 \text{ k}\Omega \angle -90°) = \mathbf{4\ k\Omega\ \angle 90°}$, $\mathbf{Z}_L = \mathbf{4\ k\Omega\ \angle -90°}$
$$X_C = \frac{1}{2\pi fC} = 4 \text{ k}\Omega,\ C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(10 \text{ kHz})(4 \text{ k}\Omega)} = \mathbf{3.97\ nF}$$

b. $R_{Th} = 0\ \Omega \therefore R_L = 0\ \Omega$

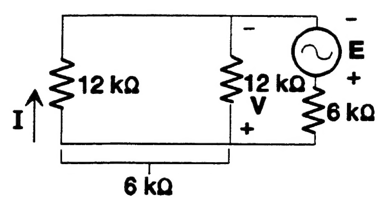
c. Undefined since $P_{max} = E_{Th}^2/4R_{Th}$ and $R_{Th} = 0\ \Omega$

48. a.



$$\mathbf{V} = \frac{4\text{ k}\Omega(\mathbf{E})}{4\text{ k}\Omega + 12\text{ k}\Omega} = \frac{1}{4}(20\text{ V}\ \angle 0°)$$
$$= 5\text{ V}\ \angle 0°$$
$$\mathbf{I} = \frac{5\text{ V}\ \angle 0°}{6\text{ k}\Omega} = \mathbf{0.833\text{ mA}\ \angle 0°}$$

b.



$$\mathbf{V} = \frac{6\text{ k}\Omega(\mathbf{E})}{6\text{ k}\Omega + 6\text{ k}\Omega} = \frac{1}{2}(20\text{ V}\ \angle 0°)$$
$$= 10\text{ V}\ \angle 0°$$
$$\mathbf{I} = \frac{10\text{ V}\ \angle 0°}{12\text{ k}\Omega} = \mathbf{0.833\text{ mA}\ \angle 0°}$$